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THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-SIXTH YEAR)

1958

EAST MALLING
RESEARCH STATION

Near MAIDSTONE

KENT

1st October 1957 to 30th September 1958

Published April 1959

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EAST MALLING RESEARCH STATION

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ADMINISTRATIVE REPORT

ADMINISTRATIVE REPORT

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Accommodated at East Malling Research Station

Telephone : West Malling 2418.

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GENERAL DEVELOPMENT AND ACTIVITIES

As its name makes clear, the prime objective of the Society is to promote experiments in horticulture and, if in this Forty-sixth Administrative Report of the Executive Committee, we tend to put on record the names of the people who help and describe the organization that contributes to that end, we should like Members to realize that the purpose of our existence is never lost sight of. The Research Report which follows leaves no doubt about the matter.

Thus the big event of the year has been the only too brief sojourn with us of the Visiting Group of the Agricultural Research Council. Their help and advice regarding the next six years' research programme were invaluable, and we are gratified that they appear to have found little in the present one to criticize.

Obituary

We had hoped to omit this paragraph altogether this year; but, as we write, we feel we should record the sudden death of Professor E. J. Maskell of Birmingham University just before Christmas 1958. Professor Maskell represented the Royal Society from 1945-54, after which he was co-opted as a member of the Executive Committee. Despite many commitments, he found time to take a close interest in the Station's research work and rendered valuable service to the *Journal of Horticultural Science* as a specialist editor on its Publication Committee.

We must also record with regret the sudden death in September of our old friend Sir Stephen Tallents. Apart from his many other interests, some of us will always associate him with willows; it may not be generally known that the weeping willow grown from a cutting from a tree beside Napoleon's tomb at St. Helena, and which has now grown into such a fine tree by the lake-side at Bradbourne, came to us through him.

Governing Members

After the largest change-over, at least for many years, in 1957, we are grateful to have little to report in 1958. Our Vice-Chairman, Professor Bennet-Clark, was elected a Fellow of King's College, London, during the year and we hope our congratulations to him, are not too late.

Mr. A. P. Preston was renominated as Staff Council representative.

The annual Governing Members' Day was held on 24th June and attended by 20 governors. The special programme included new investigations on the irrigation of raspberries and black currants and on fruit bud development, and provided an opportunity for seeing trees on M.26 and discussing the merits of this new rootstock. The interesting stage now reached in the work on fruit tree red spider mite and its predators was also discussed.

Committees

Last year, we detailed the membership of the various Committees that help so much in the organization of the Station's affairs. This is officially the report of the Executive, and we must not blow our own trumpet, but those on the Station's staff may perhaps be permitted to acknowledge how much they value the work of the officers and members of those committees, which by no means begins and ends with attendance at meetings. In fact, the Building, Plant Prices and Farming Sub-committees all met formally apart from the regular and sometimes arduous meetings of the Finance and Executive, and all meetings were well attended. The personal friendship of committee members with the staff and their interest in one, if not more than one, side of the Station's activities means a great deal and the more they are seen at East Malling the more they are welcome. Some of the problems confronting them are detailed in the following paragraphs.

A.R.C. Visiting Group

This visit in July must take pride of place in the events of the year. The last occasion on which the Station was similarly visited was in May, 1952. The purpose of the visit is to review the Station's research programme in all its aspects and discuss the many problems arising from it with the Director and members of staff. The members of the Group on this occasion were Professor K. Mather (Chairman), Mr. D. Lowe, Mr. F. C. Bawden, Professor W. T. Williams, Professor O. W. Richards, Professor R. L. Wain, together with Sir William Slater, Dr. E. E. Cheesman, Mr. G. Samuel and Mr. P.A.C. Thorne.

Three very full days were spent at the Station and we very much appreciated the time and trouble given to our affairs and the friendly spirit in which the interviews and discussions were conducted. The effects of the visit on the research programme will be felt gradually during the next six years, and undoubtedly the Committees will be called on from time to time to assist the Director and staff in carrying out decisions arrived at.

Buildings, maintenance, land, etc.

The maintenance of the estate is a continuous and never-ending task, much of which could never be accomplished without the efforts of the Station's maintenance staff.

At Bradbourne House, the redecoration of the Great Hall was completed early in the year and was crowned by a visit from the Secretary of the Pilgrim Trust, Lord Kilmaine—it will be remembered that this work was rendered possible by a grant from the Trust. We should like here to pay tribute to the skill and craftsmanship of members of our maintenance staff who have carried out this and much other highly skilled work at Bradbourne, another instance of which is the lovely walnut panelling that now adorns the back staircase.

The newly constructed Discussion Room at the Laboratories is another acquisition, largely built by our own staff, that has already seen good use, for staff discussions, lectures, meetings, to say nothing of the new film society and rehearsals for the Christmas party.

During recent years the stoolbeds, fruit tree nurseries etc., have gradually moved from Newgates to the lower land on Park Farm where, as the Farm Report shows, some forty acres is now locked up in a long-term nursery rotation. This left the Newgates packing shed widely separated from the land it was erected to serve. The old barn at Park Farm has now been adapted for the sorting and packing of nursery material (in considerably greater comfort than formerly) and was ready for use for the 1958-9 harvest. The Newgates shed will be used to house farm implements.

We must not forget that, despite all that is said about buildings, the experimental farm is the most important part of the Station's laboratories. The acute need for more land was made abundantly clear to the Visiting Group but, as yet, surrounded as we are by industrial and residential developments, no alleviation has been possible, while the long-recognized dangers of using land for fruit crops after an insufficient resting period have been newly demonstrated recently, in spite of all efforts towards the rapid restoration of fertility and uniformity. In the meantime we do what we can, but the difficulty of finding even quite small pieces of land, suited to particular needs, increases annually. As possible, replacements of and additions to the farm machinery are being made each year, so that we can be equipped to meet the needs of modern farming and our peculiar research requirements. The housing of farm workers is another continual problem. The lodge at the Grange, occupied for many years by the late Mrs. Henson, whom older members of staff remember presiding over the teapot in the early twenties, now accommodates another farm worker ; nevertheless, the need for more cottages is still pressing.

During the winter forty-eight ornamental trees were planted at Bradbourne, which will eventually replace some of the lovely trees there that are now growing old. In addition to those donated by Mr. Fromow, three have been given by members of staff. Further trees will be planted in the New Year.

Numerous smaller tasks connected with the buildings have been completed. Two rooms in the Manwaring Building have been redecorated and are now occupied by Dr. Harris and Mr. F. A. Roach. Three garages for the smaller houses at Church Fields have been built and a fourth is under construction. Two bus shelters have been put up near the East Malling village green. Farm and laboratory buildings have been repainted, as have been some of the greenhouses according to schedule, and the various properties kept in good order. Land has been ceded to the Kent County Council to facilitate the construction of a footpath in Bradbourne Lane.

The Grange and Canteen

Although a few rooms were unoccupied in the early part of the year, for several months the Grange has been practically full, which shows that it still fills a real need. But, in face of ever-rising costs, it is impossible to maintain standards at the Grange at existing charges, so all rents will be increased on 1st November, 1958. The Canteen, which was originally started in a small way by members of staff in 1941, has been the cause of much anxiety. The year 1957 ended with a large deficit and, despite increased charges, heavy costs, particularly for labour, and a fall in the number of regular supporters made it obvious that the Canteen could not be continued without further large losses. The Canteen Advisory Committee gave much time and thought to ways and means and, after its usefulness to a substantial section of the staff had been confirmed, it was decided, with the backing of the Executive Committee, to continue for a limited period to provide lunches and teas as heretofore. It is hoped that 1959 will show this policy to be justified.

Overseas Experience

The Society has established a fund to enable members of staff, especially the younger ones, who have a genuine interest in the growing of fruit, to visit fruit growing districts overseas to see how local orchard problems are met and thus to widen their experience. It should be emphasized that the fund will not be used to prolong visits to research institutes abroad or for attendance at Congresses, etc., a real need that is already generously provided for by the Agricultural Research Council and other bodies.

Fruit growing problems in East Anglia

In April 1958, a sub-committee appointed by the Executive consisting of Mr. Neame, Mr. Mount and Dr. Tubbs, ably assisted by Dr. Montgomery, toured East Anglia to inform themselves whether or not there existed problems peculiar to that district which were unlikely to be solved through research already in progress or contemplated. After a well-attended conference at Anstey Hall, Cambridge, twelve fruit farms in Norfolk, Suffolk and Essex were visited and we should like, here and now, to record our indebtedness to all the advisory officers and fruit growers who assisted to make the tour a comprehensive and valuable one, particularly Mr. B. D. A. Tucker and Mr. Giles Tuker.

While the sub-committee was impressed by the need for more local experiments in different parts of the region, in which we might co-operate with N.A.A.S. officers, there appeared to be no important fundamental problems calling for special research facilities additional to those already available.

Fruit Storage Experiments

As many Members are aware, with their co-operation, experiments in the storage of Cox's Orange Pippin have been in progress since 1956. Surplus fruit from these experiments was marketed and those who have donated apples will like to know that their contributions have already materially benefited the Blackman Research Scholarship Fund, the building of the Discussion Room and the work of the experimental farm.

Finance

The Research and Experimental Farm Accounts

It is symptomatic of the care and efficiency with which the Station's finances are now managed that, for the third year running, the draft accounts for the year 1957-8 were ready for consideration by the Finance Sub-Committee in October, only eight days after the end of the financial year, while the fully audited accounts were ready as usual by the December meeting.

The importance attributed to the Station's work by the Agricultural Research Council is witnessed by the fact that the total grants to the Station for salaries and maintenance, including the cost of the experimental farm, now exceed £225,000. Staff salaries etc., are fully met by the Council and an increase of £12,396 reflected the improvements that came into effect in July 1957. Provision for research facilities is assisted by the annual grant from the membership fund and a few minor sources of income. We have frequently drawn attention to the heavy cost of the experimental farm ; but as our wages bill, now over £40,000, accounts for two-thirds of the total expenditure no further comment is needed. However, we may well remark on the revenue from produce and crops that amounted to nearly £35,000, an increase of £4,426 over 1956-7, which, though it did not meet the wages bill, enabled the cost of running innumerable small and financially unremunerative experiments to be kept slightly below the sum sanctioned by the Council.

The East Malling Research Station Association

The Association, consisting as it does of fruit growers, professional and amateur, and others interested in horticultural research for its own sake, is in many ways the backbone of the Station and it is galling to report that we have not only failed to increase the numbers beyond 2,000 but have actually lost 21 Members during the year, the figure now standing at 1,916—surely only a small proportion of those who might benefit from membership. It may be as well to remind Members of the use that is made of their subscriptions.

Primarily the membership fund must be used for ' benevolent ' purposes, such as cannot be provided for by the Agricultural Research Council, but which are nevertheless essential to an undertaking like East Malling that employs something over 300 people. Nevertheless, one-third of each Member's subscription goes directly towards research, by a long-standing agreement with the Council. Another one-third covers such items as substantial grants towards the scholarship fund, provision for farm pensions, staff amenities and a generous contribution to the new fund for overseas experience alluded

to above. The surplus swells the accumulated fund and enables the Association to hold such properties as the Grange and assist from time to time when capital expenditure is needed for which no grants from the State can be made.

Against this, each Member receives the Annual Report every year and has the privilege of obtaining a share of surplus plant material—e.g. Mother trees of virus-tested varieties of fruits are first offered to Members. In addition, in 1958, he was invited to attend five open days, to hear of the latest research findings, and if he was unable to come he received a stencilled report shortly after. Recently a new privilege enables him to receive advance copies of reports on subjects of immediate interest, later to be published in the Annual Report ; the report of the fire-blight disease of pears is already in the hands of Members.

These notes may not be news to existing Members, but we hope they may encourage them to show non-members how much the Association helps research and eventually the Industry itself. Only in this way will membership be maintained and increased.

The year's accounts that follow speak for themselves.

The East Malling Research Station Association Income and Expenditure Account

1st October 1957 to 30th September 1958

Expenditure	£	s.	d.	Income	£	s.	d.
Research Grant	1,350	0	0	Subscriptions and Donations	4,161	18	8
Evening Class Fees	13	0	0	Miscellaneous Receipts	1	12	0
Staff Amenities	75	0	0	Interest on Investments, Loans and Deposit Account	201	16	8
Netball Pitch	90	5	0	Refund of Income Tax	46	16	6
Scholarship Fund	600	0	0	Sales of Annual Report Index	367	7	5
Farm Pensioners Fund	250	0	0				
Annual Report Index	11	1	3				
Travel Fund for Orchard Experience Overseas	500	0	0				
General Expenses	1,265	13	6				
Surplus	624	11	6				
	£4,779	11	3		£4,779	11	3

The East Malling Research Station Association Balance Sheet

at 30th September 1958

	£	s.	d.		£	s.	d.
Accumulated Members' Fund :				Freehold Property at Cost :			
Balance at 30.9.57	16,291	18	9	Fircroft, Grange and 31 Buckland Lane, Maidstone	11,359	14	9
Add Surplus for the Year	624	11	6	Investments at Cost—General Fund (Valuation 30.9.58 £3,469)	4,500	0	0
	16,916	10	3	Scholarship Endowment Fund :			
Surplus on rentals	45	16	7	Investments at Cost 8,063 3 0 (Valuation 30.9.58 £7,738)			
Scholarship Endowment Fund	10,953	4	7	Cash at Bank 2,890 1 7			
Farm Pensioners Fund	583	1	4		10,953	4	7
Sundry Creditors	91	9	7	Loans	640	0	0
				Cash at Bank	1,137	3	0
	£28,590	2	4		£28,590	2	4

Members' Days

In December the work of the Plant Protective Chemistry Section was discussed with practical demonstrations of some of the methods used in studying spray damage, the formulation and application of insecticides, and the recovery and analysis of the residues. Attention was drawn to the considerable loss of pear crop caused by organo-mercurial sprays.

As in previous years, Members co-operated in the tests of storage quality by sending Cox's apples

from some 160 orchards and in February were able to see the part of each sample that had been kept in the scrubbed gas store. The results were reviewed and arrangements made for the treatment of the trees from which samples would be taken next year. The relationships between fruit size, cell size and storage life were discussed.

As the Annual General Meeting on 13th May was in the newly redecorated Great Hall, the informal farm walks in the afternoon were to objectives near Bradbourne. These included apple mildew, frost, the rootstock trials on the light soils of Larkfield Plantation, and propagation.

East Malling's part in the collaborative undertaking to provide improved planting material for the fruit grower was outlined in July. Long-term programmes for breeding raspberries, currants, gooseberries, and apples were described. Good progress had been made in the selection of high yielding clones of Loganberry and Royal Sovereign strawberry, and in the production and field testing of virus-tested strawberries.

Research on plums was reviewed in August, including methods of tree building, gage varieties, rootstocks, and the more important diseases.

Amos Memorial Lecture

This year it was once again the turn of Wye College to act as host to the many growers, scientists, and students who assembled for the tenth Amos Memorial Lecture. It was delivered by Mr. F. C. Bawden, of Rothamsted Experimental Station, who spoke on viruses and virus diseases. The full text of this stimulating lecture appeared in the 1957 Report.

Staff

The main changes in the senior staff were detailed in last year's report. During 1958, these changes have been gradually taking effect. As from the 1st October of this year, Dr. Harris finally retired from the position as head of the Pathology Section, that he had held since 1941 ; in future he will be devoting himself full time to administrative duties in his capacity as adviser to the Director.

There have been comparatively few changes in the research staff, though there are several to record among the clerical assistants.

In February, the Director was appointed a corresponding member of the Academy of Georgofili, an Italian society founded for the progress of agriculture, of public economy, and of natural sciences.

In the Pomology Section D. W. Way, who was here for a year as a student of the Royal Horticultural Society in 1951-2, came from the Pershore Farm Institute in August to take over the strawberry investigations from Miss Fromow, who had resigned in February because of ill-health. We are sorry to record the resignation for a similar reason of Miss Nicoll, who had assisted Mr. Garner with propagation experiments since 1947. She was succeeded in June by N. G. Smith, from Manchester University.

In the Statistics Section, G. M. Jolly, who since 1951 had been particularly associated with the planning and analysis of trials conducted at Experimental Horticulture Stations and elsewhere by members of the N.A.A.S., resigned in December and he and Mrs. Jolly (*née* Miss E. C. Thompson) left Kent to start farming in the West of Scotland. In June A. H. F. Brown accepted a post with the Nature Conservancy. In July, we welcomed P. Sprent, formerly a lecturer in mathematics at the University of Tasmania, and, in September, C. S. Moore, who had worked here in two consecutive years as a temporary recorder during summer vacations, came to fill the post vacated by Mr. Brown. D. A. Holland returned from his year's study at Aberdeen in September, so by the end of the year the Section was at full strength once more after a difficult period.

On 1st October, 1958, Dr. B. D. Bolas, a member of the Imperial College Staff working in collaboration with the Physiology Section, retired. Dr. Bolas came to East Malling in 1940 primarily to collaborate with Dr. W. A. Roach in the plant injection and spectroscopic investigations, subsequently working with the war-time mineral deficiencies team. In more recent years, he has been working in collaboration with the Physiology Section. I. F. Bird returned to the Imperial College in October 1957.

Dr. Posnette succeeded Dr. Harris as head of the Pathology Section on 1st October, 1958. We congratulate him on winning the Jones-Bateman Cup, awarded triennially by the Royal Horticultural Society, for his outstanding contributions to our knowledge of the virus diseases of horticultural crops. He is the fourth member of the East Malling staff to be awarded the cup since 1930. If we may anticipate, we should also like to congratulate him on the award of the degree of Doctor of Science by Cambridge University in November 1958. Dr. Crosse will continue to assist him as deputy head of the Section. R. Cropley, who assists in the virus investigations, was seconded to Rothamsted Experimental Station for six months from January. In October 1958 we welcomed R. T. Burchill from Long Ashton to assist in the work on airborne diseases of fruits.

In the Entomology Section L. A. Lockerish resigned in June to take up a teaching post; in April Miss M. Gratwick came to us from The Imperial College field station, Silwood Park, where she had worked on the bio-assay of insecticides.

We greatly regret to record the retirement of Dr. F. W. Andrews who had been attached to the Scientific Liaison Section, in September. Dr. Andrews has struggled against ill-health for several years.

New appointments in the Assistant (Scientific) grade—thirteen in all—are recorded in the Staff List. Miss J. C. Wood and D. Blogg (Pomology) resigned in January and September and P. J. Godfrey (Statistics) in November. We congratulate Miss M. R. Peters (now Mrs. Newton) on her marriage in July. Mrs. E. M. Showler (Plant Analysis) who may be better remembered as Miss Kidwell, resigned in February after fourteen years' service at the Station. D. F. J. Deer and J. A. Pinder have also left during the year. The staff of the Pathology Section seem to have been inspired with a desire to travel. Miss J. M. Richardson left for Georgia U.S.A. in December 1957, Miss D. Lawrence for Vancouver in March and Miss R. J. Blogg for Australia in August. Miss W. M. Reed (P.P.C.) resigned in August also.

On the farm, it is a pleasure again to have few changes to report. We congratulate M. Cole of the Experimental Greenhouses on his marriage to Miss C. C. Macnamara of the Imperial College staff. Our only regret is the need to record the death of J. A. Brooker after twenty-eight years at the Station.

In the office there have been several changes. Last year we congratulated Mrs. Coney (Miss J. M. Coy) on her marriage; she finally retired to private life at the end of 1957 after twenty-six years service. Her place as secretary to Mr. Littlehales was taken by Miss P. B. Mace in April. Miss F. D. S. Gold, personal secretary to the Director since 1951, resigned to take up a post with the B.B.C. in March and has been succeeded by Mrs. R. Cook. In March also, Miss J. C. Irving, secretary to Mr. Hoblyn, left to be married and was replaced in May by Miss E. J. Lambie. Other members of the clerical staff who have left are Miss K. M. Wickham in April after twelve years and Mrs. I. M. Carlile in November 1957.

The scientific staff of the Bureau was augmented by the appointment of G. E. Fidbury in January.

We always end this section of the report by acknowledging the assistance of the officers and members of the various internal committees who help to solve the day-to-day problems that are constantly arising. After a peaceful period this year's Canteen Committee (Chairman: G. A. Booth) have been particularly helpful in the search for a solution of difficulties detailed elsewhere.

Organized Visits

The first staff visit this year was to the National Fruit Trials at Brogdale on 2nd July. On arrival the party, some 60 in number, were welcomed by the Director, Mr. J. M. S. Potter, who described the farm and outlined how the trials were conducted. They were then taken on a tour of the trial grounds by Mr. Potter and his assistants and were greatly impressed by the progress made in the short time since the Fruit Trials were moved to Brogdale from Wisley. In the afternoon the Chairman's farm at Macknade was visited, and the party was taken round by Mr. B. D. Neame. Pears occupy an important place at Macknade but Mr. Neame drew attention to many interesting points also regarding apples, black currants, cherries and hops, and progress was slow owing to the lively discussions that ensued. At the close of the day a quick look was taken at the packhouse of East Kent Packers. The staff were particularly pleased that Mr. F. Neame was able to come round with us as well as his son.

On 30th July, the famous nurseries of Brenkman Bros. at Bobsham were the objective, where the visitors were received by Mr. J. D. N. Brenkman and taken round many acres of nurseries by him and his son, and members of his staff. Here fruit trees were seen being raised on a vast scale, with meticulous attention to detail and superb organization, and there seemed to be few unsolved problems.

On 18th August a bus-load went to see some typical Weald farms in the parish of Marden. Mr. William Day gave a brief review of the history of the farms seen in the morning, then he and Mr. Edward Day conducted the party round the fruit and hops on two farms, finishing at the packhouse where a long discussion took place on methods of bulk harvesting, mechanization in the packhouse, marketing and labour management.

In the afternoon Mr. John Wheeler showed his farm, where different methods used under similar conditions could be compared. On both holdings much of the acreage was under standard Bramley's and hops. This was the first visit on which much of the time was spent on hops, including the examination of two hop-picking machines.

We have pleasure in recording our thanks to Mr. Potter, Mr. Neame, Mr. Brenkman, Mr. Day, and Mr. Wheeler, and to their staffs, for so hospitably receiving our staff and for taking so much trouble to ensure that the visits were both profitable and enjoyable.

Social and Athletic Activities

B. F. Self succeeded Miss Fromow as Social Secretary for the year. Two new clubs were formed, the Film Society and the Skittles Club. While they cater for rather different sections of the staff, both got off to a flying start, the first holding very well-attended monthly meetings and the second being particularly appreciated by the farm staff.

Nearly all activities have been supported well during the year. Three athletic clubs now arrange fixtures against the Members. The Cricket Club had to concede defeat, but the Tennis Club won their match, while the Hockey Club, which played a return match, shared the honours with their opponents. At first, throug'. the loss of several enthusiasts, it seemed that the new Netball pitch would not have as much use as was expected ; but, thanks very largely to the efforts of the Social Secretary, the Club was rejuvenated and had a good season, winning ten matches out of fourteen. Both the Table Tennis and Squash Clubs have been well supported, the former even contributing an item to the annual party.

On the social side, as anticipated, the re-opening of the Great Hall was celebrated with a party at Bradbourne in February conveniently linked with St. Valentine's day After some vicissitudes, a floor show was arranged, in the organization of which we think Miss Seymour, Mr. Self and several Clubs shared the honours, to say nothing of Mr. Oxley who catered for refreshments in quite a new form unabashed. Music, again, has played a large part in entertainments organized by the staff, while the Play Reading Club even had a summer party at Bradbourne ; though the connection between the search for literary clues in the arboretum and the reading of plays is beyond us. Of course, there was a Children's Party in July and this year it was fine, much to the relief of the parents. We gather that many of the children look forward enthusiastically to this event each year, indeed, even as they grow older, they still come and seem to enjoy it immensely, not least the tea provided by Mrs. Tubbs, who understands very well the kind of food that the young appreciate.

We have no space to enlarge on other activities which included, boating, dancing, the annual Kew-Wisley road race (in which for once E.M.R.S. were not last) and a snow battle. Finally, we must not forget to mention that the farm, to say nothing of the helpers among the research and administrative staff, seemed much to enjoy the Harvest Supper, despite a wet evening.

Postgraduate Students

At the end of September 1958, Dr. Harris took over responsibility for students from Mr. Hoblyn. We are very glad to report that the first award of a Blackman Research Studentship was made during the year and, in September, M. G. Morris came to us from Cambridge, to start a period of three years study in the Entomology Section. Although no other students, save members of staff, were working for higher degrees during the year, two, one from South Africa and one from India, have now been registered and have commenced their studies.

In March G. H. Freeman was awarded a Ph.D. degree in Statistics for a thesis dealing with experimental design, and M. M. MacNeill an M.Sc. degree for a dissertation on glasshouse culture ; A. R. N. Gorrod was also awarded a Ph.D. degree by Glasgow University for work completed before joining the staff here.

All other long-term students worked in the Pathology Section. After nine months study of storage diseases, Dr. Z. Borecki returned to Poland in January, while Dr. A Mezzetti also completed his studies and returned to Italy in April. The work on virus diseases was materially assisted by the sojourn with us, during a period of sabbatical leave from March to August, of Dr. R. M. Gilmer from Geneva, New York. D. J. Butt left for East Africa in August and was succeeded in September by another Colonial Office student, D. A. Burdekin. For shorter periods, W. Reed, an Empire Cotton Growing student, worked in the Entomology Section during the autumn and early summer before taking up a post in Nigeria; M. El Adhari, from Tunisia, assisted with Pomology recording during August and September.

We still get many applications from abroad, but few applicants have the qualifications or special interest in horticultural research for which we look in a postgraduate student at this Station.

Temporary Recorders

After nine years of the scheme, it is rewarding to report that, as we write, three present members of staff first worked at East Malling as temporary recorders in their vacations. A fourth is numbered among our postgraduate students.

The number of applicants in 1958 rose markedly ; nineteen out of forty-three were accepted, two for the third year running, many of whom showed excellent promise as potential research workers.

During these years we have built up a most worthwhile connection with many University Departments, so that it is exceptional now for recommended students not to prove a valuable addition to our recording staff while they are here.

Plantation Assistants

This year's team of 10 is predominantly male and was augmented by a Dutch student, F. Groeneveld, who is here for one year. It is, perhaps, hardly surprising, that we now get fewer applications from women. From the Station's point of view a more evenly mixed team is preferable, because some tasks are performed better by the female sex.

We note with satisfaction that internal lectures to plantation assistants have been assisted from outside and would record our indebtedness to Messrs. F. A. Roach, N. Stewart, C. R. Favell and Miss J. Buttfield, all of whom contributed much-appreciated talks.

We congratulate Michael O'Keefe to whom the annual prize presented by the Worshipful Company of Fruiterers was awarded. He is expected to remain with us until Spring 1959. Again it was difficult to decide between the merits of more than one candidate for the award.

Staff Discussions

With a staff as large as it is now, it is difficult to find enough subjects of general interest to all and, mainly for that reason, as last year, such discussions were limited to four, of which those dealing with tree growth and breeding for resistance to pests and diseases may be mentioned. In the meantime more specialized discussions, involving the personnel of two or three Sections, continued with unabated vigour, to say nothing of the animated exchanges of ideas on research methods. When he visited us in March, Professor R. Brown gave two talks on his work on cell physiology, one for the specialists and one for the more lay-minded, and stimulated much interest.

Research Tours

Dr. Flood returned to the Station in May. Following a period of study in California with the aid of a fellowship from the Kellogg Foundation, he was enabled to visit Canada under a grant from the Hatley Foundation, spending most of his time at Queen's University, Kingston.

After attending the Congress at Nice, in May, Drs. Montgomery and Rogers visited the Centre de Recherches Agronomiques du Sud-Ouest, Pont de la Maye, Gironde. At about the same time Messrs. Hoblyn and Garner were present at the H.E.A. Channel Islands Conference.

The Council also sponsored visits to the Netherlands by Mr. Goode in May, when he spent time at Wilhelminadorp and Wageningen ; to Holland, Germany and Switzerland by Mr. Tew in June ; and, in the same month, to Germany by Mr. Maggs.

With the aid of the Wellcome Trust and the International Union of Biological Sciences, Miss Keep went to Montreal and also visited Ottawa, and Geneva, New York.

At the invitation of the American Phytopathological Society, Dr. Kirkham attended their Golden Jubilee meeting in Indiana and also visited several research institutes in the United States.

Dr. Pearce visited Brussels in September, and also Grand Menil, near Gembloux. Mr. Hoblyn attended the formal inauguration of M. Delbard's Verger Expérimentale at Malicorne, France, also in September.

Finally, we must report Mr. Garner's departure in the same month for the Rubber Research Institute of Malaya—but more of this after he returns early in the New Year.

Visits to other research institutes and tours of fruit-growing districts etc. in various parts of the United Kingdom are too numerous to mention individually ; but we may perhaps pick out the one by seven members of the Pathology and Protective Chemistry Sections to Long Ashton. The exchange of ideas that took place with their opposite numbers there was most valuable.

Collaboration

It seems scarcely credible that it is only twelve years since the formation of the N.A.A.S. and eight years since the foundation of the Experimental Horticulture Stations, so large do these two now established institutions loom in our lives. Every Section reports one or another project in collaboration with the Service, either on grower's plantations or at one of its Stations. With the retirement of Professor Wallace, the Working Party, which guides the fortunes of fruit experiments at these Stations, has been reconstituted and strengthened. Dr. Montgomery is now Chairman, while Mr. Hoblyn remains convenor, the latter now also officially representing the Station on behalf of the Director. Mr. F. A. Roach, regional fruit specialist, who resides with us, has also joined the Working Party.

During the year the irrigation trial on apple trees under grass at Luddington has been started, while all is ready for planting the pear manurial trial at Efford during the winter 1958-9. These are only two of many projects carried out with N.A.A.S. help.

The collaboration with the Nuclear Stock Association in raising and multiplying virus-tested strawberries is already well known. Recently, together with Long Ashton, a nursery at Taunton,

where a virus-tested clone of Loganberry is being multiplied up for distribution through the Association, was examined for trueness-to-name and freedom from disease.

The work here on hop pathology leads to a close association with growers and research workers, particularly at Wye. In collaboration with the association of growers of new varieties of hops, a survey of outbreaks of verticillium wilt in tolerant varieties was made this year. Following farm trials of new wilt-tolerant varieties, three (J2, D1 and D3) have now been released and a description of them appears in this Report (see p. 161).

Our thanks are due to the authorities at Writtle for the continuing facilities afforded us for the study of acaricides, phytophagous mites and beneficial insects in relation to the control of the fruit tree red spider-mite.

We should not end this section without mentioning fire-blight. Following intensive investigations here to establish the nature of this dangerous disease, which has been affecting many pear trees, the full authority of the Ministry is being brought to bear to try to eradicate it. In this we have kept in close touch with pathology specialists in the Service.

Gradually, during the past thirty years our attitude to those with whom we work has been changing. At one time we used to regard it as a rather rare privilege for research workers to be allowed to carry out investigations on growers' farms and elsewhere ; we still do—but nowadays our collaborators are often as deeply involved in an investigation as we are, so that what was at one time a rather one-sided affair has developed into a concerted effort. We welcome the change and are glad to be in it.

Scientific Societies and Conferences

The XVth International Horticultural Congress at Nice in April was attended by Drs. Rogers, Knight, and Montgomery. Dr. Rogers with Dr. Modlibowska presented a paper on the use of water sprinkling against frost damage.

Miss Keep attended the Xth International Congress of Genetics at Montreal in August, where she read a paper, contributed jointly with Dr. Knight and Mr. Briggs, on breeding raspberries for aphid resistance.

At the meeting of the American Phytopathological Society at Bloomington, Indiana, in August, Dr. Kirkham delivered a paper on host factors in the physiology of disease.

Dr. Pearce attended the conference at Brussels organized by the International Statistical Institute in September and gave a paper on multivariate analysis at the meeting of the Adolphe Quetelet Society, which followed it.

At the symposium on Soil Microbiology at Liverpool in August, Dr. Mosse demonstrated some aspects of her work on mycorrhizae and Dr. Sewell read a paper on the direct observation of *Verticillium* in the soil. Mr. Holloway attended a symposium on herbicides at Oxford in March. The Station was represented at a number of A.R.C. conferences : of plant breeders at Aberystwyth by Dr. Knight, Mr. Tydeman and Miss Keep ; of workers on insecticides, fungicides and weedkillers at Rothamsted by Drs. Dicker, Kirby, and Moore ; on Verticillium wilt of lucerne by Dr. Sewell.

Many members of staff attended and took part in the regular meetings of learned societies. A paper was read by Dr. Dicker on the effect of chemical control of vectors on the incidence of virus in strawberries at a symposium of the Association of Applied Biologists and by Mr. Maggs on the effect of pruning on the pattern of subsequent growth at the December meeting of the Society for Experimental Biology. Dr. Moore addressed the conference of advisory pathologists on apple mildew and on spray deposits in relation to disease control, and Dr. Massee was in Belfast for a conference of advisory entomologists in July.

Information Services

Correspondence, exhibits, lectures and demonstrations

Direct enquires about subjects under investigation included numerous telephone calls and over 1,400 letters, most of which were answered by the Scientific Liaison Section. Visits to fruit farms were closely linked with research in progress and numbered 52, of which 40 were concerned with entomological problems. Warnings of the occurrence of 'Mills Periods' at the Research Station were supplied to the Maidstone Branch of the Kent N.F.U. from April to June.

An exhibit of frost damage to apples was shown at the Marden Fruit Show. A collection of pears grown in the Bradbourne Gardens was displayed on the R.H.S. Fruit Group table in the late autumn. At Chelsea, we staged an exhibit showing the winter storage of hardwood cuttings, which brought the advantages of this technique to the attention of many nurserymen and gardeners. In the British Pavilion at the Brussels Fair, horticultural research was represented by an illuminated

panel displaying rootstock influence on tree growth and root distribution in the soil, prepared with collaboration from the Station. We helped the N.A.A.S. by providing plants for exhibits in various parts of the country.

Of the twenty-eight lectures given, nineteen were to fruit growers, and the rest to societies connected with universities, schools, and youth organizations. Members of staff took part in brains trusts at Sudbury in Suffolk and at the R.H.S. London. A pruning demonstration was given to the ACE Growers in Essex.

We again assisted with judging at all the major fruit shows, including Marden, East Kent, Wisbech, and the Cherry and Soft Fruit Show, and in the orchard competitions in Suffolk and West Sussex.

Visitors

Of the 1,800 visitors who came to the Station during the year over 400 came from overseas. They included from Australia Dr. D. W. Goodall, who worked with us from 1939 to 1946, and who is now Director of the Tobacco Research Institute, Queensland, and from Canada, Dr. H. Hill, Chief of the Horticultural Division, and formerly one of our postgraduates, Dr. W. H. Upshall, Director of Vineland, Ontario, and Dr. C. C. Strachan, Director of Morden, Manitoba ; from Ceylon, Dr. T. Visser, of the Tea Research Institute, a former postgraduate here ; from Denmark, Dr. N. Dullum, Director of Blangstedgaard ; from France, a party investigating the organization of research composed of Messieurs A. Reifenberg and M. R. Coutanceau from Paris and Messieurs R. Bernhard and R. P. Remy from Bordeaux ; from Germany, Professor F. Hilkenbaumer of the University of Bonn ; from Holland, Mr. M. A. Erkelens, head of the Plant Certification Service with a party of Chief Inspectors ; from India, Dr. L. B. Singh, who took his Ph.D. degree here in 1947, and is now director of the Horticultural Research Station, Saharanpur ; from Kenya, Dr. R. Child, Director of the Tea Research Institute ; from Nigeria, Mr. D. J. Parkinson, Permanent Secretary, Ministry of Research and Information ; and from South Africa, Dr. H. Shaw, a former member of our staff, now Director of the Wattle Research Institute. We were also delighted to welcome Dr. R. Brown, Head of the A.R.C. Unit of Cell physiology, Oxford, Dr. E. C. Childs, Director of the A.R.C. Institute of Soil Physics, Cambridge, Mr. M. V. Laurie, Director of the Alice Holt Forestry Research Station, and Dr. D. C. Manderville, Colombo Plan Scientific Adviser.

In addition to the usual parties of students from universities, training colleges, farm institutes, and schools in this country we received a party of Dutch advisory officers accompanied by Mr. J. J. van Hennick, a party of French horticultural teachers, and members of the Société Nationale d'Horticulture de France. The N.A.A.S. Pathologists spent a very full day in September discussing the work on plant diseases. Other members of the N.A.A.S. and officers of the Local Education Authorities kept in touch with the Station through the annual two-day visit, the specially arranged rehearsals of Members' Days, and the refresher courses on rootstock identification and on nettlehead disease of hops.

Distribution of Experimental Material

The fruit tree nurseries are an integral part of the experimental farm and so an account of the season 1957-8 as it affected our propagation department, both in the field and in the packing shed, appears in the Farm Report.

The Distribution List for the Season 1958-9 was sent out to Members in July as usual and by September most orders had been received. Supplies of the Malling Merton woolly aphid resistant apple rootstocks were available for offer in fair quantity, though by no means enough to supply the demand for the most popular of them. With these, we were also able to offer the older rootstocks M.VII, M.II, and Quince A, together with a few St. Julien A and Brompton plums and Mazzard F12/1 cherry. We had hoped this year also to offer the new semi-dwarfing apple rootstock described in last year's report, M.26. Unfortunately, after 20 seasons with no evident troubles, in 1958, some of the varieties budded on this rootstock the previous July, started into growth very unevenly, resulting in a very variable ' stand ' of maiden trees. It was therefore deemed wise to withhold distribution, until the cause of this could be ascertained, to which end immediate and intensive research was initiated, as soon as the trouble was observed.

To the scion varieties offered as Mother trees was added one cherry variety, Noir de Guben, which, though not entirely free, is of minimal virus status and the best likely to be available for several years. Virus-tested James Grieve apple and Williams' bon Chrétien pear were offered for the first time. Altogether worked trees of eleven apples, eight cherries and four pears were offered, to which was added a list of virus-tested apples and cherries which can be worked on request. It may be noted that all cherry varieties susceptible to bacterial canker are now high-worked on F12/1, while certain plums that we hope to offer in 1959 will also be worked high on Myrobalan B stems.

This report tends to stress the plant material destined for distribution to Members. We should not forget, however, that the nursery exists firstly to supply research needs. During 1957-8 some 5,500 worked trees and over 6,000 rootstocks of many different kinds were grown for our own purposes, while many collections etc. were supplied free of charge to other research institutes all over the world.

Station's Publications

The publications are all listed in Part II of the Research Report. There were 61 scientific papers and 11 articles written specially for fruit growers.

Journal of Horticultural Science

Quarterly publication was again maintained, Vol. 33 containing 29 papers, of which 12 emanated from this Station. A marked tendency towards brevity has enabled more papers to be published without any material increase in volume size—a very welcome development in an international journal that tries to cover many horticultural interests.

The rise in subscription rate brought no appreciable diminution in the number of subscribers and the Journal ended the year in a stronger financial position than for many years previously.

The editorial policy will be continued for the time being pending the appointment of a joint editor from Long Ashton ; but in the meantime, the Editor would acknowledge the very real help he has had from that Station as well as from Professor W. Brown.

Library

By the time the next Report comes to be written, we shall have a new Chairman of the Library Committee. Mr. Akenhead, has been intimately associated with the library since he first arrived at the Station in April 1929 ; we therefore make no excuse for including now the following brief account of the library's development that he has given us.

A history of the library might be more diverting to write than to read, but a few notes on its development and on the part played therein by the Commonwealth Bureau of Horticulture may be of passing interest. Its Chairmen have been Dr. R. C. Knight until his death in January 1935, R. V. Harris 1935-40, H. Shaw, 1940-7 and from 1947 D. Akenhead.

When in 1929 the Bureau, whose staff then was one man, the said D. Akenhead, took up its quarters at East Malling under the directorship of R. G. Hatton, the library, consisting of some books, bulletins and periodicals, was in the N.F.U. building. The first job which Hatton set the one man was to determine, with the help of horticultural experts at home and abroad, the literature which the staff of the Research Station and the Bureau ought to see. The results were the recommendation and the achievement of a great increase in literature, especially periodicals, in the library. Not only did the Station increase its quota of journals, partly by purchase, partly by exchange, but the Bureau also contributed its share, particularly publications dealing with horticultural crops other than fruit and foreign and overseas journals.

Since that time the joint library of the Station and the Bureau has probably been one of the best equipped horticultural libraries, with regard to serious current literature, in the English-speaking world.

Next, in 1930, the Bureau was entrusted with the classification and carding according to the Universal Decimal System of all the books and bulletins. Thereafter, and until the appointment of a full time librarian at the end of 1946, it undertook this work for all the non-periodical literature entering the library and in addition saw to the bestowal of the periodical literature. It made arrangements for outside loans and the binding of periodicals.

In November, 1937, the then chairman, R. V. Harris, dealt with library interchange correspondence, D. Akenhead, acting as librarian, dealt with the classification of incoming books and bulletins and the placing of all periodical literature, a nearly full-time member of the Bureau, Miss M. Durling, dealt with the routine work in the library while the Research Station was responsible for stamping literature, for keeping stock books and for clerical work in connection with interchange.

The transfer of the library to Bradbourne was completed in April, 1940.

The arrangements outlined above continued to hold good throughout the war, during which time pressure steadily increased, so that by 1945 it became necessary to appoint a whole time librarian, and, in December 1946, Mr. S. R. Ball was appointed, Miss Durling continuing her very onerous task of assistance. Since then, with the minimum of fuss, efficient service has been rendered by these two obliging persons.

In 1947, on the departure of Dr. Shaw for South Africa, the director of the Bureau was appointed 'Temporary Acting Chairman' of the library. He is still Temporary Acting Chairman, without

regrets. He himself knows that it is no mean advantage to the Bureau to hold that position and he believes that the arrangement has not been without advantage to the Station, inasmuch as it obviates duplication of effort and ensures maximum mutual help between Station and Bureau staff.

The joint library in December 1958 contains some 2,838 books, 55,772 bulletins, 7,200 volumes of bound periodicals and it receives about 685 current periodicals. It surely has grown!

RESEARCH REPORT

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RESEARCH REPORT

RESEARCH REPORT

Part I

THE EXPERIMENTAL FARM

The total value of the fruit crop for the financial year 1957-8 was about £4,500 more than in 1956-7. However, at least as far as 1958 was concerned, this was not achieved without some difficulty. A cold dry spring followed by a very dull and exceedingly wet summer made all outdoor work difficult and expensive. Crops of most fruit plants, except plums, were heavy but the unending rain caused excessive growth of grass and weeds and hindered the harvesting of both top and soft fruits. Here at East Malling we were again fortunate in escaping the worst of the hail storms and floods which had such devasting effects in some places. The hail which fell on 23rd June only affected part of the farm and though serious, was not as damaging as in 1956. There was some slight soil erosion as a result of the torrential rains in the late summer, but nothing serious. The prolonged spell of cold winds during the latter part of March and early April severely damaged the blossom of early varieties of plums and the buds of loganberries and Malling Exploit raspberries, but apart from slight damage to unopened buds of Bramley's Seedling, there was little other frost damage to top fruit. Growth in general was very backward and the season was a late one. However, when growth finally did start towards the end of April, there was a tremendous show of cherry, pear and apple blossom and all varieties came out more or less together, thus affording ideal conditions for pollination. Early Rivers cherries were in full bloom on 3rd May and Bramley's Seedling apples on 9th May—a fortnight later than in 1957—and no strawberries were marketed until 20th June.

Experimental orchards

Top fruits

Apples.—The total apple crop, 317 tons, was the largest since 1947, most varieties yielding heavily. Some of the older trees of Worcester Pearmain, the fruit from which had been small and of poor quality, had been grubbed the previous winter ; to compensate, however, younger plantings are now coming into full cropping. Although blossom did not seem to be profuse, what there was set well and the abundant rainfall swelled the fruit to a good size, so that there was a good crop of excellent quality fruit of this variety. Both Ellison's Orange and Laxton's Superb blossomed profusely and set very heavy crops which had to be severely thinned where experimental treatments allowed. Despite thinning much of the fruit of Ellison's Orange was small and, possibly because of lack of sun, poorly coloured. Laxton's Superb on the other hand, even where unthinned, produced good-sized well-coloured fruit. Thirteen-year-old trees of this variety in the pruning trial on Churchfields West averaged 4 bushels each. The crop of Cox's Orange Pippin, 49½ tons, though satisfactory was less than expectation, chiefly due to the poor performance of this variety on M.XII, in the manuring trial on Churchfields East. These are large 30-year-old trees which, in 1954, carried 10-12 bushels per tree, whereas in this year they averaged only 4½. Certain other large trees on Kiln Field also yielded poorly. The dull rainy weather seems to have suited Cox's Orange Pippin less well than Worcester Pearmain and Laxton's Superb and in general fruit size and quality were disappointing. Our trees of Laxton's Fortune, now 13 years old, bore by far their heaviest crop to date, this variety in the soil management experiment on Churchfields West averaging 3 bushels per tree. Most of this fruit was of good size, but although sprayed with anti-drop spray and left on the trees as long as possible, much failed to colour well and the proportion of ' Fancy ' grade fruit was small. Jonathan also cropped fairly well and the fruit was of good size and quality, particularly on the lighter soil on Larkfield. This variety hangs well and does not need to be picked till after Laxton's Superb, thus extending the picking season most conveniently. Barnack Beauty again bore a heavy crop, 640 bushels, from just under 1 acre of land.

In spite of a rather poor show of blossom, crops of Lane's Prince Albert and Bramley's Seedling were satisfactory. The Lane's Prince Albert in particular gave their biggest crop since 1954. One plot of Great East which, for experimental reasons, did not receive early sulphur sprays was severely attacked by mildew and the crop somewhat reduced, but the adjacent rootstock trial more than made up. Unfortunately hail damage in June greatly reduced the value of the fruit. Although the total crop of Bramley's Seedling was 356 bushels up on 1957, fruit size was again poor in spite of the ample rainfall, and the total yield from 4 acres of mature trees was only 1,743 bushels. On the rootstock trial of this variety in Great East, where sulphate of ammonia has been used in large quantities for some years, the soil has now become very acid (pH 4·4). This may have something to do with the poor crops we have been getting recently and it has been decided to apply nitrogen in the form of nitro-chalk next year.

Pears.—The total crop of pears, almost 26 tons, was nearly five times that of the previous year and the fruit was all of good size and quality. The 36-year-old trees of Conference in the rootstock trial on Egham Field, now at 150 trees per acre, averaged 188 lb. of picked fruit per tree, or nearly 600 bushels per acre. Though this is the highest crop per tree so far recorded on this plot it is not the largest crop per acre ; this was produced in 1945 when the trees, then at 12 ft square, yielded 125 lb. picked fruit per tree or 786 bushels per acre.

The Williams' and Conference on Egham Field also cropped heavily as did all varieties in Bradbourne Gardens. Here, in 1957, frost had destroyed the crop, but this year the crop was very heavy and emergency measures had to be taken to support some of the dwarf pyramid trees. The young pears planted on Merryweather in 1956 made good growth.

Cherries.—Conditions for pollination at East Malling were almost ideal; all our three main varieties, Early Rivers, Bigarreau de Schrecken, and Turkey Heart, now 30 years old, were in full bloom within a few days of each other, the weather was kind and all set heavily. Ample rain swelled the fruit to a great size and all looked set for a record crop, but the rain went on and on, picking became very difficult and much of the fruit was ruined. The Early Rivers did not split much at first, but later wastage became heavy and the crop only averaged 6 halves per tree. Bigarreau de Schrecken carried a heavy crop but splitting and rotting were so bad that only 12 halves in all of this variety were marketed against 359 halves in 1957. The Turkey Heart saved the situation to some extent and averaged 5 halves per tree, though even their tough skins split a good deal and all had to be sorted.

The ample rain suited the young cherries, however, and those planted in Newgates Field in 1956 made excellent growth.

Plums. —The severe frost in the third week of March wiped out the Myrobalan crop and seemed likely seriously to affect other varieties of plums. It was surprising, therefore, that in the end the total crop of 26 tons was three times as heavy as in 1957. This was mainly due to a good crop of Victoria and especially to the excellent crops from the 10-year-old trees, mostly on semi-dwarfing rootstocks, on Park Farm. Here Cambridge Gage and Early Laxton averaged just over 60 lb., Victoria 112 lb., and Majorie's Seedling 101 lb. per tree. The collection of ' gage ' and other plum varieties on Deadman Field, which are now about 25 years old, were hardly worth harvesting, only Ontario giving an appreciable crop.

Soft fruits

The total strawberry crop, just over 3 tons, was almost the same as last year from a slightly smaller acreage. There was little frost damage and fruit size was good, but much fruit was lost from *Botrytis* rot.

The raspberry plantation on Egham and the much larger one on Newgates, planted in 1955, grew and cropped excellently. On Newgates, although the rows are not yet fully furnished, Norfolk Giant cropped at the rate of 4 tons and Malling Exploit at $3\frac{1}{4}$ tons per acre. The lower crop of Malling Exploit may have been due to the damage to the opening buds by cold winds in early April which scorched the young leaves severely. Norfolk Giant buds were hardly open at this time and escaped damage. Though the rain swelled the fruits well it made picking difficult and *Botrytis* was troublesome. Cane growth was tremendous, reaching a height of between 7 and 8 ft. Much of this will have to be cut off next spring to bring the fruit within reach of the pickers.

As previously mentioned, our small plot of loganberries suffered badly from the freezing winds in the spring, some primary buds being killed out. However, the cane itself was not much harmed and secondary buds grew out to produce fruiting laterals which bore a satisfactory crop.

The new black currant trials, also in Egham and Newgates Fields, bore their first crop this year and all varieties yielded satisfactorily. Mendip Cross, Wellington XXX, and Westwick Choice in Newgates averaged from $2\frac{1}{4}$ to 3 lb. per bush, and Amos Black and Baldwin in the irrigation and nitrogen trial in Egham Field $2\frac{1}{4}$ to $4\frac{1}{2}$ lb. This means that Baldwin cropped at the rate of 42 cwt. per acre, a good first crop.

Fruit marketing

The year 1958 was a very busy one in the packing shed and a somewhat disappointing one. Prices later in the season were much lower than in the previous year, and all but the best fruit was difficult to sell. However, as soon as it became obvious that there was a heavy crop generally, processing contracts were made and it was thus possible to dispose of the bulk of the crop without the necessity of sending any poor quality fruit to market. In fact no fruit below the F.G.A. 'Choice' standard and no fruit under $2\frac{1}{4}$ in. in diameter was marketed at the height of the season, and prices were on the whole satisfactory when the size of the crop is taken into consideration.

A severe outbreak of red spider, particularly in Churchfields West, resulted in much small, poor-quality fruit from parts of this plantation in spite of the ample rainfall. Elsewhere fruit size and colour were excellent, except as has already been noted on Ellison's Orange and Laxton's Fortune. The whole of the Worcester Pearmain crop, which was of excellent quality, was sold at picking time and the store usually reserved for Worcester Pearmain has been filled with poorer Ellison's Orange which it is hoped will sell better after Christmas. Our other large store has been filled with Lane's Prince Albert and Bramley's Seedling for keeping till the New Year as in the past, and the smaller stores with Cox's Orange Pippin and Laxton's Superb to be kept as long as possible. There was not enough cold storage space for our Barnack Beauty and Jonathan and these had to be barn stored at picking time and marketed in November. Most of our cherries and plums were sorted over a simple moving belt and graded into 1st grade, 2nd grade, and rejects as in the past. The fruit was marketed in secondhand tomato trays ; these are cleaned up and relabelled in the off season and when filled a paper cover with a cellophane window is stapled on. These trays are cheaper than chips, stack better, and the stapled-on cover discourages pilfering ; they can be used for all soft fruits and being, of course, non-returnable are very acceptable in the market.

Our raspberries and strawberries were sold locally for processing, but loganberries and black currants were sent to market, the former in $\frac{1}{2}$ lb. punnets and the latter in the secondhand trays already mentioned.

Fresh planting and grubbing

In this Report we give annually an account of the year's plantings and grubbings. This, however, gives little idea of the amount of long-term planning that has to be undertaken in order to fit the numerous projects into our limited acreage. The following brief summary shows how the land on our Experimental Farm is now used :

	Acres
Fruit experiments of potential cropping value	122
Laboratory studies in the field	44
Land in preparation for fruit trials	41
Nursery land, including stoolbeds, fruit tree nursery and land in preparation	70
Experimental hops	3
Arable land, etc., unsuited to experimental purposes	40
Roads, buildings, etc.	40
	360

The largest single plot planted in autumn 1958 was $1\frac{3}{4}$ acres of plums on Egham Field (E35). The varieties are Victoria, Denniston's Superb, and Cambridge Gage, all of which have been high worked on St. Julien A rootstock and planted at 15 by 18 ft. This plot has been planted to provide mature trees for future experiments and no treatments will be applied yet. A further 2 acres of Laxton's Fortune and Laxton's Superb apples have been planted on Egham Field (E29) for work on biennial bearing, with $\frac{3}{4}$ acre Lord Lambourne, Beauty of Bath, Cox's Orange Pippin, and Worcester Pearmain for insecticide-testing work close by. All trees on these two plots are worked on a semi-dwarfing rootstock and should grow into fruitful medium-sized trees well suited for experimental work. On Newgates about $\frac{1}{4}$ acre of closely-spaced apples and pears have been planted for work on weedkillers ; parts of the raspberry and black currant plantations in this field will also be used for this work. For physiological studies, $\frac{1}{4}$ acre of maiden plums have been planted on Deadman Field (D1) ; the area on Park Farm devoted to the selection, collecting, and testing of many varieties and kinds of fruit for virus is being gradually shifted to P14 on which an acre has been planted this year ; another side of the Pathology Section's work, i.e. on bacterial canker, has been catered for by planting high- and low-worked Victoria plums ($\frac{1}{10}$ acre) on Great East (G16).

Continuing the policy of replacing older plantations with material which it is hoped will be more suitable for experimental work and at the same time more profitable, the remainder of the old Worcester

Pearmain plantation on Kiln Field (K7) has now been cleared. These trees were too large for detailed work and the fruit very small and of little value unless severely thinned. The 36-year-old Cox's Orange Pippin rootstock trial on Egham Field (E32) was concluded some years ago but the trees were kept for demonstration ; the eastern half of the plot will be grubbed in 1958-9, leaving the western half for short-term work on mature trees. Additional small areas, experiments on which have been concluded, include a plum trial (N3), a few apple varieties (E30), and two small plots used in plant breeding (G5 and G6). On Park Farm approximately 1 acre of fruit plants used by the Plant Protective Chemistry Section are being replaced as well as the virus testing area (3 acres) alluded to above.

Routine spray programme

All our plum plantations were sprayed with 5 per cent tar oil during December 1957, as were the loganberries. Apart from these and certain nursery material, the only plots which received any winter wash were young trees and those where spring applications of DDT would have interfered with experimental requirements. Three applications of lime-sulphur, pre-blossom, and four of colloidal sulphur, post-blossom, were made to apples for the control of scab and mildew, plus, on later varieties, an additional spray of a preparation containing 80 per cent TMTD. Scab control was good, but mildew control was less satisfactory and shoots had to be hand-picked twice on some plots as well. Aphids were kept in check by the addition of DDT to the first two lime-sulphur sprays, and sawfly by adding BHC to the fruitlet stage spray. In 1957 two sprays of chlorbenside had given excellent control of red spider, but in 1958 the same two sprays plus one of metasystox proved useless. The metasystox killed the adult mites, but the chlorbenside did not control the eggs, and by the end of the season, a heavy infestation had built up which resulted in much bronzing and early leaf fall in some places.

Two applications of lead arsenate were generally used against codling moth, but although this was effective, the deposit persisted till picking time on some varieties and much fruit had to be wiped by hand before being packed for market.

The pear spraying programme of lime-sulphur and DDT before and captan after blossom was continued unchanged in 1958 except that metasystox at 12 oz. per 100 gal. was added to the petal fall application for the control of pear sucker.

Summer sprays for cherries and plums were the same as in 1957.

Little trouble has been experienced recently with raspberry cane midge, so our raspberries were only sprayed four times in 1958—once with $2\frac{1}{2}$ per cent lime-sulphur and DDT against cane spot and aphids, twice with derris against raspberry beetle, and a fourth spray of Bordeaux 4:6:100 in the autumn to combat a severe outbreak of spur blight. Damage caused by this disease is often more apparent than real, but it was thought advisable not to take any chances with our young plantation. Black currants were sprayed at the ' grape ' stage with lime-sulphur against big bud mite and later with metasystox against aphids and black currant midge. In Egham Field a severe outbreak of leaf spot developed and Bordeaux mixture was applied to prevent heavy leaf fall.

Last year's programme for both runner beds and cropping strawberries was repeated ; it should perhaps be mentioned that for many years all strawberry plants have been dipped in a solution of 10 oz. nicotine per 100 gallons of water before planting to ensure their being aphid free.

Arable crops

The acreage under arable crops remained the same as in 1957, fresh plantings being about equal to the land cleared. Some of the land cleared, however, had been under close-planted experimental trees for some years and had become so badly infested with couch that it had to be fallowed. The actual area of crops, therefore, was slightly less at 108 acres.

The weather, though disastrous for cereals, suited peas so that on the whole results were better than expected.

Potatoes.—Nine acres of Craig's Royal and 8 acres of Majestic were grown. All were sprayed three times with copper and the haulm burned off with sodium arsenite in late August, but even so, the Craig's Royal suffered severely from blight, about 20 per cent of the tubers of those lifted late being infected. Of the Craig's Royal, 6 acres were lifted in August and sold straight from the field, yielding 8 tons per acre. Considerable difficulty was experienced in disposing of these owing to taint. Possibly this was because they were on land previously occupied by nursery material which had been sprayed several times with BHC two years previously. The remaining 3 acres of this variety (in another field) were harvested in October and sold readily. All Majestic were harvested in October.

Peas.—In contrast to last year, 1958 was one of our most successful years for peas, because although the cold dry spring made germination very slow, later rains gave good growth and satisfactory yields. Ten acres of Kelvedon Wonder and Perfected Freezer were grown for quick-freezing and yielded 31 cwt. and 51 cwt. per acre respectively. Ten acres of Lincoln and Surprise were grown for canning

and yielded 31 cwt. and 48 cwt. per acre. A residual herbicide was used on part of the acreage and gave good control of most broad-leaved weed seedlings, particularly fat hen, which until the advent of chemical weed control was our chief enemy. The advantage of this type of weedkiller for peas is that it obviates wheel damage caused by running over the growing crop.

Cereals.—The weather in August soon banished all hopes of a bumper harvest and 4 acres of spring oats had to be ploughed in. However, all barley and wheat were harvested, and though much of the grain had to be dried, yields were satisfactory. Thirteen acres of Proctor barley gave 22 cwt. and 12 acres of Cappelle wheat 30 cwt. per acre. The 8 acres of Banco wheat were cut with a binder and stacked so as to provide straw for packing. Half of this has been threshed and yielded 34 cwt. per acre.

Fortunately 4 acres of Cocksfoot seed were harvested without much loss and the yield was excellent—7 cwt. of cleaned seed per acre.

Seventeen acres of ryegrass and clover were grown, of which eleven were made into silage and six into hay. The first cut of hay was of good quality but the second cut lay so long in the field that it was only fit for litter. In addition to the grass 60 tons of pea haulm were also ensiled. As more fodder was available 46 steers were yarded for the winter, 10 more than in the previous year.

Experimental nurseries

Although the number of trees and bushes required for new plantings at East Malling was not unusually large, 1958 was a very busy year in the nursery. Considerable numbers of trees were required for outside trials on growers' farms, for N.A.A.S. Experimental Horticulture Stations, the National Fruit Trials at Brogdale, and the National Cherry collection at Bordon. Further, as the shortage of land for large scale field experiments becomes more acute, more and more trees and root-stocks are needed for intensive experiments in the field and in the glasshouses. Both weed control and spraying were difficult, but growth was good and the quality of the trees and bushes excellent for most stock/scion combinations.

As mentioned elsewhere (p. 80), stocks lined out for budding on the site of an old stoolbed grew very unevenly, a fact which emphasizes once more the great care that has to be taken in selecting land for the production of uniform experimental nursery material.

The mild open autumn again delayed leaf fall and the very wet December held up all outside work, so that it was not possible to dispatch surplus plant material to Members and research institutes as early as we should have liked. However, this work was completed by the end of January 1959, by which time 239 consignments had been sent to Members and Fellows in Great Britain and 86 dispatched overseas.

The year 1958 was also a busy one in the stoolbed areas where the total crop of shoots was 358,271, of which 188,840 were fit to line out for budding, an increase of 85,515 on 1957. In January all stools and layers were carefully cut back in order to lower them and remove any deadwood; the apple stools were top dressed with nitrate of soda in May, and Epsom salt has been applied for the last three years. All these factors, combined with the ample rainfall, probably contributed to the increase in the number of first grade rootstocks produced.

As with fruiting plantations, apple mildew was troublesome in the stoolbeds, and sulphur spraying should be continued later in the season to give control in bad years.

Experimental glasshouses

During 1957-8 the replacement of the below-sill level parts of the timber upright supports of the virus houses was completed. During the progress of this work it was possible to re-arrange and renew some of the heating components in the main duct ; all condensate pipes were renewed and rigid connexions replaced with flexible connexions to eliminate future strains and fractures due to differences in expansion and contraction between branch and main condensate pipes.

The new aluminium and timber glasshouse built during 1957 has been quite satisfactory during its first full year in use ; it has enabled temperatures between 57° and 75° F. to be maintained at any time of the year, irrespective of the outside temperature.

The outside mist propagation bays erected in 1956 have been modified ; polythene has been fitted on top of the dutch lights to form a roof and the sides can now be opened or removed in very warm weather. A thermostatically controlled electric soil-warming cable has been installed in part of the rooting medium. A higher humidity can now be maintained with less frequent sprinkling, since the unit is virtually enclosed, and the medium kept at 65-70° F. irrespective of outside temperatures and the amount of water required to maintain maximum humidity.

The indoor mist equipment has been extended and modified so that rooted cuttings, potted up in John Innes compost with the addition of more sand and grit, are kept on the same bench for a week

or so with a reduced amount of mist and bottom heat. By this means the transition stage between "full mist" and "no mist" has been successfully overcome, and softwood cuttings of many species have produced plants with a good root system in two to three months.

In some instances, e.g. *Prunus* spp., apical buds die or fail to develop, even although roots are formed within a few weeks ; lateral buds do not always develop, especially if the cuttings are taken in late summer, but giberellic acid applied to the leaves at 100 p.p.m. has often induced such buds to develop into shoots.

An automatic watering device for trees and bushes in pots outside has been tried with encouraging preliminary results, although the porous pot, which indirectly controls the supply of water, was found to be sluggish in its response to dry and wet conditions.

In an endeavour to gain partial control of the temperature under glass during the summer, part of a small glasshouse roof was hinged at the eave and additional side ventilators were fitted to enable a comparatively large volume of air to pass through the glasshouse quickly without the aid of machinery.

Although the temperature on the warmest days was about 5° F. lower than an unshaded glasshouse with normal ventilators, it was 7° F. higher than a similar house with heat absorbing glass raised above the ordinary glass roof ; this confirms the previous observation that the use of heat absorbing glass is approximately equivalent to lath blinds and better than any other method not involving the mechanical movement of air.

The number of spray applications under glass has been fairly constant at intervals of seven to fourteen days during the summer and less frequent in the winter ; although red spider is not now the problem that it was a few years ago, it is rarely absent and sometimes increases rapidly on plants that, for experimental reasons, cannot be sprayed. Sprays used inside consist mainly of TEPP, nicotine, and karathane, but DDT, colloidal copper, and endrin are also used when necessary ; additional sprays outside include tar oil, parathion, and lime-sulphur.

Apple and pear trees have again been chilled artificially and forced early in the year to provide material for the Pathology and Entomology Sections ; here, too, giberellic acid has been useful in prolonging the season of trees under glass which had apparently ceased to grow.

The number of seedlings, plants, and trees continues to increase and to meet present day needs a succession of plants is now produced all the year round.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

In spite of early frosts, and a wet and cloudy summer, fruit yields in general have been good.

The 19 published papers, listed on p. 12 include a review of advances in rootstock research, showing the remarkable progress made in under 50 years, and summarizing the latest recommendations for apples, pears, plums, cherries and peaches (E486).

Tree fruits

About 86 acres of tree fruit trials have been maintained, but only those experiments in which new developments have taken place will be mentioned in this report.

Rootstocks

It is now 23 years since Sir Ronald Hatton published his results from the four original apple rootstock field trials ; the results of three of these trials have now been brought up to date. Reports of the rootstock effects with the varieties Lane's Prince Albert and Cox's Orange Pippin, up to the age of 35 years, have already appeared (E485, E497), and the results with Worcester Pearmain are in the press. The fourth variety, Bramley's Seedling has now scion rooted to such an extent that comparisons between trees on different rootstocks are no longer valid.

Trees on the new clones, MM.104, MM.106, MM.109, MM.111 and M.XXV have generally maintained their early promise. An up to date report on the growth and cropping of Cox's Orange Pippin on the new rootstocks and on some of the original Malling rootstocks appears on p. 47. Trees on MM.104 are outstanding for yield.

A study of fruit size in relation to leaf area and number, was begun this year with two apple varieties on rootstocks covering a wide range of vigour.

The release of the semi-dwarfing apple rootstock M.26, forecast in last year's Annual Report (E487) was postponed because in spring 1958 certain varieties, notably Lord Lambourne and Fortune, showed irregular bud-break of budded trees, resulting in a patchy appearance of the nursery row in June. Buds of Cox, Worcester and Laxton's Superb, on the other hand, grew regularly and well ; and by October most of the late-starting trees of Lord Lambourne and Fortune had caught up the others. A series of studies of factors likely to affect callusing and bud-break on M.26 has been started, with the object of explaining this unexpected behaviour. Meanwhile the numerous established trees on M.26 have continued to do well.

Blossoming and fruit set of pears was particularly good, and the yields from the trials of Conference on Quince rootstocks were excellent. The 38-year-old trees of Conference on Quinces A, B, and C produced 25 per cent more than the previous best in 1956. In the trial on Merton Quinces, now 19 years old, the yield was twice the previous best.

Two trials of Conference and Williams' Bon Chrétien on clonal free pear rootstocks were grubbed in December 1958. Four selections from the main trial were retained for further trials. Four other rootstocks in the main trial and five in the subsidiary trial were rejected, because much of the fruit was relatively small and gritty.

The Chinese pear *Pyrus calleryana* and certain pear seedlings are being examined as possible dwarfing stocks. Trees of Conference on *P. calleryana*, now in their fourth year, have made less growth and fruited more heavily than on Quince A.

Preliminary work with the Canadian plum Mansan suggests that this may be a useful rootstock for Oullins Golden Gage.

In choosing plum rootstocks for high working, paucity of lateral shoots on the leader is a great advantage. Brompton, Pershore, St. Julien A and the hybrid E480, all have this quality and also have straight leaders

In the 12-year-old trial of semi-dwarfing plum rootstocks all four varieties cropped well, the

heaviest yields being from trees on St. Julien A and Marianna. In the 7-year-old trial of similar rootstocks, Rivers' Early Prolific on Pershore and on Marianna carried 10 lb. of fruit per tree.

Incompatibility

Variations in the degree of compatibility of individual trees of the same stock/scion combination are being investigated further. A nursery trial has been planted to examine whether differences in compatibility of individual trees of three pear varieties on Quince B rootstock will be transmitted by buds of these trees. Four-year-old trees of Williams' Bon Chrétien on five selected single layer clones of Quince A are now showing marked growth differences. A paper on growth and union structure of double worked pear on quince was published (E498).

Some results are now appearing in a peach/plum incompatibility trial designed to test whether incompatibility of this type can occur without direct contact between the incompatible graft components. Trees of Hale's Early peach on Brompton rootstock with ring or patch grafts of Myrobalan B in the rootstock stem have smaller girths, and this year carried a significantly higher crop than similar trees with Brompton ring grafts.

Histology

Phloem and cambial structure are being examined in clonal rootstocks differing in their effect on the growth and fruiting of scion varieties. The main commercial apple, plum and cherry rootstocks in addition to rootstocks of experimental interest, are included in the plants selected for this work.

Fibre length has been measured in rootstock and scion varieties differing in the mechanical strength of their stems.

The development of wound callus is being studied in budded rootstocks, and in comparable unworked rootstocks from which small areas of bark were removed with a cork borer.

Propagation

Studies in collaboration with the Plant Physiology Section, including experiments with hardwood cuttings, and further work on softwood cuttings under intermittent mist spray, have continued.

Two reports on the 1956 mist propagation experiments were published (E480, E481), and the growth in the nursery of apple cuttings rooted under mist in 1957 has been recorded. In 1958 the mist frames were enclosed with a polythene roof, and soil-heating wires were installed in two half-frames. The effects of growth substance treatment of the cutting, bottom heat, and different times of transfer to the nursery are being tested on two apple and two plum rootstocks.

In all the hardwood cutting experiments the material was winter-stored with a controlled temperature minimum of 45° F. Four apple, and four plum rootstock varieties were again included in the main storage experiment and reasonable establishment in the nursery was achieved with all of them. Other experiments were concerned with the effects of varying the length of the cutting, the behaviour of quince cuttings in winter storage, and the influence of differing growth vigour of the source shoots, induced by pruning.

Rooted cuttings of apples and plums from the winter-storage bins are usually bedded out in the nursery for a year before being lined out for budding. In order to save a year in the nursery, budding directly into the cutting five months after taking the material from store is being tested on a small scale.

Root studies

A paper on root development of apples on five soil series was published (E485) and one on the effects of grass sward and clean cultivation is in the press.

Pruning

Apple pruning trials with Worcester Pearmain, Laxton's Superb and Cox's Orange Pippin again cropped heavily, especially those trees under regulated and renewal pruning methods. A severe outbreak of red spider caused premature defoliation especially on Cox, and fruit size was reduced – the bulk falling within the $2\frac{1}{4}$–$2\frac{1}{2}$ in. size grade.

With the co-operation of the N.A.A.S. an apple pruning trial was established on a grower's farm in East Kent, comparing regulated trees on MM.104 with renewal pruned trees on M.II.

In the pear pruning trial involving treatments designed to secure early bearing from Doyenné du Comice, the unpruned trees yielded a few fruits at two years old.

On pyramid plum trees pruned in summer, less branch breakage occurred than on similar trees that were either unpruned or grown as standards. The unpruned trees are, at present, carrying the heaviest crops.

Fruit thinning

In collaboration with the Plant Physiology Section, the apple thinning trial with the variety Sunset was continued.

Analysis of fruiting

The studies on the induction and development of fruit buds were continued in conjunction with the work on biennial bearing.

An investigation into the causes of poor setting of certain trees of Cox's Orange Pippin was begun, and preliminary experiments to influence fruit set are being carried out. Further work on the degree of fertilization of the flower required for fruit development has been carried out.

A special survey of poor or irregular cropping of pears in the Eastern Counties was made, and the data are being considered in relation to factors known to affect yields.

Biennial bearing

The trials in collaboration with the N.A.A.S. on the use of copper sulphate as a defoliating agent are providing useful information on seasonal effects, now that the second trial is cropping for the first time since the treatment was applied. After two good crops the trees in the first trial have reverted to biennial bearing and this trial has been concluded.

A further trial of naphthalene acetamide as a blossom thinning spray was carried out, using a commercial formulation. Results were encouraging and the trials will be continued next year. An attempt to use CIPC as a total deblossoming spray, as reported for ornamental trees in the U.S.A., was unsuccessful.

The dissection of spur buds from the two previous hand defoliation trials in 1954 and 1956 has revealed interesting differences in the pattern of development of the buds following treatment. Experiments are now being carried out to study the seasonal and other causes of these differences.

Staking and tying

In a trial with Czar plum trees most of the six methods of tying (three using string or rope and three patent ties) are supporting the trees adequately, but one is completely satisfactory. All ties had to be loosened at least twice in the first year, and at least three times this year, the second year after planting. Serious breakage of one patent tie was found after only two years' use.

Weedkillers

Preparations have been made for a trial of the persistent weedkillers monuron and simazin around young apples and pears (see also under Small fruits).

Breeding

Rootstocks.—About 1,300 cherry seedlings from self- and cross-pollinations among the East Malling selected Mazzards were planted out in the spring for examination as possible dwarfing rootstocks for cherries. Further batches of seed were obtained in the summer from crosses between *Prunus avium* and *P. tomentosa*, *P. pseudocerasus* and *P. incisa*.

Attempts to intercross the pear and the quince for the production of rootstocks combining wide compatibility with pear varieties and good propagation qualities were continued, and about forty fruits have been obtained from a cross between Beurré Superfin pear and Angers quince. Fruits from a similar cross last season contained no seeds.

Scion varieties.—About 6,000 seedlings from 27 families of self- and cross-pollinations between apple varieties, raised with the object of combining good fruit qualities with lateness of flowering, were planted out during the spring and selection, based on lateness of leafbreak and on resistance to apple scab and apple mildew, is being carried out. A further 30 families raised with the same object will be planted out during the coming spring.

Collaboration with the Entomology Section on the production and testing of apple seedlings for resistance to the woolly aphid continued, and further resistant seedlings were planted out for fruiting.

Varieties and clones

The dessert apple trial including Tydeman's Early Worcester and Tydeman's Late Orange, and the field trial of Cox's Orange Pippin propagated from trees of different cropping and blossoming histories have been maintained.

Large differences in yield were recorded between the different peach varieties that are included in the rootstock and pruning trials in the Bradbourne gardens.

Trees of the main commercial apple varieties are being established on their own roots.

Small fruits

The small fruit trials now cover about 6½ acres.

Variety and strain trials

Strawberries.—Results of the trials comparing heat treated and untreated clones, up to 1957 were published (E488). In 1958 the heat treated clones again showed greater vigour, but differences in yield were much smaller than before. Spread of virus may have affected these results.

Plants of Merton Princess, Royal Sovereign, Talisman, and of four other varieties which were deblossomed as maidens, unexpectedly failed to produce an increased yield in the following year.

A new trial was planted to compare virus-tested clones of Cambridge Favourite, Cambridge Vigour, Redgauntlet, Cambridge Rival, Merton Princess and Talisman with Royal Sovereign and Huxley.

The new clone of Royal Sovereign, M.415, again yielded more heavily than M.48, the difference this year being about ten per cent.

Loganberries.—The yield of three-year-old plants of five virus-tested Loganberry clones was adversely affected by frost damage at bud break in March. In spite of damage to many of the primary laterals at this period, however, the plants carried a fair crop, much of the fruit being borne on secondary laterals. The mean yield per plant of the most promising clone was 9 lb. (about 3 tons per acre). Differences between strains were noted in secondary lateral production, where the primary laterals were killed. Fruit borne on secondary laterals was of good size, but it ripened later than on primaries, giving rise to an extended picking season.

Propagation and maintenance of stocks

Strawberries.—Thirty-one clones were multiplied in gauzehouses, and a nucleus of over 40 virus-tested clones was maintained as pot grown plants in an insect proof greenhouse. Three isolated runner beds provided material for field trials.

Loganberries.—Sub-clone L478 from an original East Malling selection, virus-tested and propagated in collaboration with Long Ashton Research Station, is now available through the Nuclear Stock Association.

Blackberries.—Virus-tested plants of Bedford Giant, and of a sport of this variety with few thorns, are being raised for a trial of yield and growth characters.

Breeding

Raspberries.—Breeding of raspberries resistant to the virus vector *Amphorophora rubi* was continued in close collaboration with the Entomology Section. Seven genes have been identified for resistance to the three biologic strains of the aphid so far recognized ; two of these genes together give adequate protection against all three strains. A paper on this subject was presented at the 10th International Congress of Genetics at Montreal.

The transfer to certain parent lines of direct virus resistance and of other economic characters was carried a stage further.

The inheritance of ability to recover from frost by producing secondary fruiting laterals is being investigated and this character is being transferred to parent lines.

Currants.—A number of allotetraploids of black currant × red currant varieties have been made for backcrossing to black currants in breeding for improved strig characters. Various tetraploids of red currant and of black currant have also been raised for use as parents.

In the transference of genes controlling fruit size from gooseberry to black currant varieties, 124 seedlings were planted out. These comprised crosses of the allotetraploid black currant × gooseberry to both diploid and tetraploid black currants.

Gooseberries.—Families derived from selfing Leveller, Whinham's Industry and Broom Girl fruited this year and preliminary selections were made. Work on the improvement of fruit size in hybrids of Hunter's semi-spineless varieties was continued.

Cultural measures

Strawberries.—The small scale trial comparing spaced plants with matted rows of Talisman showed little difference in yield in the first main crop.

The suitability of the varieties Cambridge Favourite and Cambridge Vigour for the hill-mat system of culture is being tested. Since the vigorous heat treated clone of C. Favourite forms very many runners, the matted rows formed by it are already dense.

Weedkillers

Strawberries.—The weedkillers 2,4-DES applied monthly at 3 lb. per acre during the summer, plus dinoseb at 2 lb. per acre in the autumn again gave good weed control without appreciably harming Royal Sovereign. A paper was prepared for the Fourth British Weed Control Conference. A trial comparing the effects of CIPC and propham, at different times of application, was started on Red-gauntlet and Cambridge Favourite.

Black currants.—MCPB applied to Mendip Cross at up to 8 lb. per acre in August 1957 caused no serious damage and the trial is being continued. A trial using simazin and monuron is being started.

Raspberries.—MCPB applied in August 1957 resulted in some damage. Applications have been repeated this year. Dalapon applied in November at up to 10 lb. per acre had no adverse effect on Malling Exploit, but control of couch (*Agropyrum repens*) was disappointing. Simazin and monuron are being tested on raspberries.

Frost damage investigations

The 1957-8 winter was outstanding for frequent changes from very cold to mild conditions. The lowest temperature was reached on the evening of 24th January, when the grass minimum on the Bradbourne frost plot fell for a short time to 2·5° F., a temperature normally registered only during very cold winters. Because of this short duration and the 6 in. deep snow cover, practically no winter injury was caused in fruit plantations.

During this winter various types of sprinklers were tested for their suitability for spring frost control. The Jeffree sprinkler, which is no longer in production, has been replaced on our experimental plot by an impact sprinkler with an adjustable jet. A new automatic control system has been devised which starts some of the sprinklers at 32° F., and others at 29° F., but if a temporary rise of temperature is followed by another fall it restarts all the sprinklers at 32° F. This takes advantage of initial supercooling and results in economy of water.

Extensive damage to buds, caused by frosts in March and April, was recorded on apricots, bush peaches and some cherry and black currant varieties. A preliminary study was made of the effect of tying in black currant bushes on resistance to spring frosts, and on yield.

In the frost laboratory the study of frost resistance at different stages of floral development was continued on varieties of peaches, cherries, plums, and on apple seedlings.

Research continued on the physiology of frost resistance of blossoms. It was established that 'hardening' of blossom by low temperature is associated with a higher percentage of total sugars and a lower percentage of water in the flowers. The reaction of several different varieties of apple to low temperature hardening was investigated.

The differences in frost resistance at various stages of flower development and between different varieties of apple, plum and cherry were studied, as also were the effects of mineral nutrition, light intensity and 'silver leaf' infection of plums. In all these experiments, samples of buds or flowers were taken for analysis of sugar and water content. The effect of a glycerol spray on frost resistance of apple blossom was investigated.

A paper on automatic frost control by water sprinkling was published (E483) and was reproduced in two French journals. A paper on the same subject was given at the 15th International Horticultural Congress in Nice.

Mycorrhiza

A comparison was made of mycorrhizal infections produced by inoculation with two different fungi, an isolate of *Pythium ultimum* and an *Endogone* sp., using apple seedlings grown in pots in autoclaved and steam sterilized soil. Inoculations with *Endogone* sporocarps resulted in 100 per cent infection in both types of soil, while only one in ten seedlings developed mycorrhiza following inoculations with *Pythium ultimum*. In steam sterilized soil eight out of thirty control seedlings developed mycorrhiza but in autoclaved soil none became infected. These results will be published shortly.

A paper has been prepared describing a method of obtaining regularly 80-100 per cent germination of *Endogone* resting spores. Such high and regular germination of chilled aseptic spores is the result of stimulation by a dialysable substance produced by actively growing soil organisms.

Walnuts

Many varieties carried heavy crops this year. Following the wet summer many of the nuts had imperfect shells, but the varieties Secrett, and Stutton Seedling had a high proportion of good quality nuts.

Horticultural meteorology

Wind studies in orchards with differently spaced trees were continued. A comparison was also made between the run of the wind over bare land and that over land under different tree densities. A report on this work is in preparation.

The usual meteorological records were maintained.

Publications During the Year

E480 Singh, S. M., Garner, R. J., and Hatcher, E. S. J. (1957). **The behaviour of softwood cuttings of apple in the open under intermittent mist and in a closed propagation frame.** *J. hort. Sci.*, **32**, 239-47.

E481 ———, ———, and ——— (1957). **The influence of source and environment on the performance of apple leaf-bud cuttings.** *J. hort. Sci.*, **32**, 248-53.

E483 Rogers, W. S. (1957). **Automatic frost control by water sprinkling.** *Comm. Grower*, No. 3227, 934-5.

E484 Coker, E. G. (1958). **The root development of black currants under straw mulch and clean cultivation.** *J. hort. Sci.*, **33**, 21-8.

E485 Preston, A. P. (1958). **Apple rootstock studies : thirty-five years' results with Lane's Prince Albert on clonal rootstocks.** *J. hort. Sci.*, **33**, 29-38.

E486 Rogers, W. S. (1957). **Advances in rootstock research.** *J. R. Agric. Soc.*, **118**, 64-75.

E487 ——— (1958). **Malling 26, a new semi-dwarfing apple rootstock.** *Rep. E. Malling Res. Sta. for 1957*, 48-9.

E488 ——— , and Fromow, M. G. (1958). **The field performance of heat-treated strawberry clones.** *Rep. E. Malling Res. Sta. for 1957*, 50-6.

E489 Garner, R. J., and Hatcher, E. S. J. (1958). **Aspects of rootstock propagation. V. The behaviour of root cuttings from plants of different age of establishment.** *Rep. E. Malling Res. Sta. for 1957*, 57-61.

E490 Knight, R. L., and Keep, Elizabeth. (1958). **Developments in soft fruit breeding at East Malling.** *Rep. E. Malling Res. Sta. for 1957*, 62-7.

E491 Tydeman, H. M. (1958). **The breeding of late flowering apple varieties.** *Rep. E. Malling Res. Sta. for 1957*, 68-73.

E492 Knight, R. L., and Keep, Elizabeth. (1958). **An early sport of a red currant.** *Rep E. Malling Res. Sta. for 1957*, 74.

E493 Keep, Elizabeth. (1958). **Cytological notes.** *Rep. E. Malling Res. Sta. for 1957*, 75-8.

E494 Trowell, G. F. (1958). **Weather conditions during 1957.** *Rep. E. Malling Res. Sta. for 1957*, 79-82.

E495 Coker, E. G. (1958). **Root studies. XII. Root systems of apple on Malling rootstocks on five soil series.** *J. hort. Sci.*, **33**, 71-9.

E497 Preston, A. P. (1958). **Apple rootstock studies : thirty-five years' results with Cox's Orange Pippin on clonal rootstocks.** *J. hort. Sci.*, **33**, 194-201.

E498 Mosse, Barbara. (1958). **Further observations on growth and union structure of double-grafted pear on quince.** *J. hort. Sci.*, **33**, 186-93.

E500 Thompson, Eleanor C. (1958). **Descriptions of some apricot varieties.** *Fruit Year Book*, 117-25.

E503 Knight, R. L., Keep, Elizabeth, and Briggs, J. B. (1958). **Resistance in the red raspberry to *Amphorophora rubi* (Kalt.).** *Proc. X int. Congr. Genetics*, **2**, 147.

II. STATISTICS AND RECORDS

Design and analysis

This year there have been several developments relating to the work done for other Sections. In particular, the electronic computor at Rothamsted has increased the computing facilities of the Section by about a third. In all, analyses were carried out on 942 bodies of data although no theses were in preparation ; of these, 227 were dealt with by the electronic computor, and the back-log of 131 analyses reported last year was entirely cleared. The new facilities were especially useful in dealing with data on the mineral content of plants, because the difficulty here arises solely from the large number of analyses needed, usually all to be done in the same way. The computor has, however, more exciting possibilities, because it makes practicable methods of analysis which would previously have been regarded as too laborious. Multivariate methods have yet to take their place among the established techniques, but current research gives hope of their doing so.

During the year more members of the Section have taken part in its advisory work. As a result it is hoped that closer liaison will be secured with those who seek statistical advice, a need that has been increasingly felt as more attention has been given to the classification of experimental situations. Experience has emphasized that no analysis of data should ever be merely ' routine ', quite subtle changes in the problem under study sometimes calling for large modifications in statistical technique.

The designing of trials has continued at about the usual level. Some recently developed designs were used in practice for the first time, but for most experiments simple methods have sufficed, and remain the ideal.

Record Office

The filing of data has continued as usual. An attempt is being made to go through old records and put everything in order with a good system of indexing. In 45 years the Station has accumulated about 7,500 files, and at least 80,000 data are added each year. This represents a vast and unique store-house for future research, but too often the old files are consulted only because someone happens to remember one of them. By sound indexing it is hoped to increase the usefulness of the collection and to conserve it for the future.

Statistical research

Methods of experimental design and analysis

Increasing experience has been gained of the methods developed at East Malling for planning a succession of trials on the same plants. This has led to study of the variability of plants so used and to consideration of the best designs for different circumstances, but work on the mathematical aspects of the subject has largely ceased.

Attention has been given rather to designs with unequal replication. It has been realized for some time that much unimportant information is obtained when trials are planned with all treatment means equally well determined and all comparisons made with equal accuracy. Attempts have been made to adjust replication so that emphasis is placed where needed, and this is now being done more often and with greater assurance as the mathematical aspects become better understood. A design recently developed for this purpose was used in a strawberry variety trial at Brogdale.

Statistical studies of biological problems

Multivariate methods have been extensively used, initially in cases where there was enough background knowledge to help in the interpretation. Results have been most encouraging, especially with *component analysis* and *factor analysis*. With both these methods the aim is to discern and disentangle the biological factors behind the quantities measured, and component analysis has proved useful in the study of the many growth records that can be taken on a tree. With crop records there is the additional complication that the measurements taken sometimes include an arbitrary element on account of gales, rotting, etc., and here factor analysis is proving helpful.

Further work has been done on the calibration of apples and pears. It is not proposed to take this further on present lines, because multivariate methods are likely to prove more powerful, but it now appears that the efficiency of calibration can be markedly improved by the use of records of tree size and previous crops simultaneously.

A preliminary investigation has begun on the variability of intensively grown trees, the intention being to relate the number of fruits in any one year to the number of fruit buds in that year and the

number of fruits in the preceding year, account being taken also of the growth of the trees. As a result it is hoped to establish both a suitable size for experimental plots and the best variates to use for calibration.

A study has also begun on the variability of raspberries and black currants, the intention again being to find a suitable size for plots and some indication as to calibrating variates.

Reports have been published on the field measurement of leaf areas (M43) and extension growth (M44).

Field trials

The investigation of methods of restoring land uniformity, conducted in collaboration with the Fruit Nutrition Section, having reached the end of its first phase, i.e., the use of a three-year-crop rotation, the results were examined and a report published (U18). The rootstocks planted out on the remainder of the trial, involving a seven-year rotation, made good growth in their maiden year.

The uniformity trial on apples continued to provide detailed records, which have proved valuable in some of the problems described above.

Publications During the Year

M43 Freeman, G. H. (1958). **A comparison of methods of measuring leaf areas in the field.** *Rep. E. Malling Res. Sta. for 1957*, 83-6.

M44 Jolly, G. M., and Holland, D. A. (1958). **Sampling methods for the measurements of extension growth of apple trees.** *Rep. E. Malling Res. Sta. for 1957*, 87-90.

III. PLANT PHYSIOLOGY

Collaboration has continued between the Plant Physiology Section and the Research Institute of Plant Physiology under Professor F. G. Gregory, and the following report includes work of the latter's staff carried out at East Malling.

Studies of growth and form in fruit trees

Field experiments

Last year it was mentioned that the large-scale ' stock-on-stock ' experiment had been completed ; data from it are now being analysed on the A.R.C. electronic computer at Rothamsted and the analysis of one sampling has already been received.

The experiment on the effect of extreme pruning regimes and of de-blossoming on tree growth has now passed its fifth season after planting. Preliminary examination of the *girth* records shows the cumulative effects of the treatments : for example, in all four scion varieties on M.XVI the average girth of the very lightly pruned trees is 9 per cent greater than that of the heavily pruned, while de-blossoming has not yet had much effect. On the precocious M.IX, on the other hand, the effect of pruning is slight compared with that of deblossoming, which has caused an average increase in girth of 18 per cent. Too few records have yet been obtained to link the amount of crop with the difference in girth between the fruiting and deblossomed trees, but there are already indications that such a relationship will differ markedly for the different varieties : for example deblossoming has markedly greater effect on girth of Laxton's Superb than it has on Cox's Orange Pippin trees, although Cox has carried heavier crops.

An experiment was mentioned last year in which one-year-old trees were allowed to develop various numbers of shoots in either their second or third years, and the effect on growth was reported ; further analysis of the data has shown that the distribution of increment is little affected by the number of shoots, and that, apart from a reduction in the proportion of leaves in the second year (equivalent to a higher net assimilation rate), the increment was similarly distributed in each of the two years.

Two experiments were carried out on Victoria Plum to test the effect of various treatments on the production of wide crotch angles. In one, in collaboration with the Pomology Section, indolyl-butyric acid in lanolin was applied to the cut-back maiden stem in March and either left in place or removed later ; once again crotch angles of the top three branches were not greatly improved. In the other experiment, however, branches at right angles to the stem were obtained by removing six or twelve leaves from the terminal cluster of unexpanded leaves at the tip of a rapidly growing shoot. The subsequent growth of these branches was improved by cutting out the main stem above the defoliated region after the branch angles had become fixed. These main stems had been obtained by cutting one-year-old trees hard back and allowing a single shoot to grow ; similar defoliation treatments with normal nursery trees, however, in the year of bud growth, gave very disappointing results on two varieties of apples and one each of plum, cherry and pear, possibly due to less vigorous growth of these shoots at the time of treatment.

Growth of young trees under particular conditions

Rooted layers were grown in pots under four degrees of shade from 20 per cent to full daylight to determine the effect on the form of the tree and its carbohydrate status. Results are not yet complete, but it has already emerged that shading does not appear to alter the distribution of increment between new stem and old, but only its amount ; further, that while the greatest increment was made in full daylight, when most secondary shoots developed, the largest leaves, the greatest leaf area and the longest shoots were produced in 70 per cent daylight.

Another experimental method of modifying the distribution of growth, in particular the way in which secondary thickening is laid down, is by flexing the main stem, as has been found for forest trees swayed by the wind. In a small experiment in 1957, and in a larger one in 1958, mechanical flexure has been applied to one-year-old apple stems by day or by night. The results so far obtained support the previous findings that thickening is greater in the line of movement than across it.

The effect of the position of the source bud upon subsequent growth of the scion is discussed in a paper on p. 83 of this report.

Solution culture methods continue to be investigated, and this year growth in the main group of apple rootstocks and worked trees was very satisfactory ; some trees, especially unworked M.XXV and M.26, made a greater gain in weight than comparable plants grown in John Innes compost, and

in general there were very few deaths. In this system 13-in. pots are sunk in the ground and contain nutrient solution in special polythene liners ; the solution is continuously aerated, and is changed several times during the season. The emphasis this year was on determining the importance of *Phytophthora* in solution culture, and though experiments conducted with advice from the Pathology Section suggested that this fungus is not the direct cause of death of apple trees under these conditions, nevertheless the avoidance of contamination of the root system both before and during culture appears to have been most beneficial.

A special system of solution culture in flat glass troughs has been used successfully with apples and willows this year for studying root growth ; with the root system thus spread out, serial photographs show the growth of individual roots admirably.

Growth of individual shoots

The data obtained in the intensive observations of leaf and internode growth mentioned last year have been summarized, and some of the results have been prepared for publication.

Internal factors which control growth in stoolbed shoots also continue to receive attention. An attempt has been made to locate more precisely the effects so far ascribed to the ' tip ' of the shoot, comprising all the leaves in the terminal cluster and the apical meristem itself. To assist in determining the role of the lower leaves in shoot growth two groups of leaves, one fully mature and the other younger, were darkened by covering them with aluminium foil for periods of three, six, or nine days : these treatments were compared with defoliation of the same regions. Final results are not yet complete, but it was observed that immature leaves darkened in this way suffered a severe check in expansion, and that in some abscission was induced.

An experiment was carried out to compare the foliar structures displayed by lateral buds induced to grow out by removal of the very young leaves with those of buds growing out when the shoot is cut back to various levels. When a shoot was cut at the level of the 10th or 14th expanded leaf below the tip, the branches which grew out showed the presence of about four bud scales followed by a number of transitional structures before true leaves appeared ; as shoots were cut back less severely, so there was a reduction in the number of structures below the true leaves, until by cutting off the stem within the terminal cluster, or by defoliation treatments in that region, branches were induced on which no transitional structures occurred, the first true leaf being preceded only by two opposite asymmetric leaf-like organs at the base of the branch.

Carbohydrate resources

The analyses begun last year of samples of bark and wood taken monthly from seven positions in six-year-old trees of M.IX/IX and M.IX/XVI have been continued. These are providing information on seasonal changes in the carbohydrate fraction.

Changes observed in the ' concentration ' of carbohydrate (expressed as the percentage of the dry residue after extraction) suggest a rapid utilization during initial spring growth followed by an almost equally rapid replenishment ; a second decline soon occurs, when shoot extension is active, and this is built up again when shoot growth comes to an end. Glucoside, sugar, starch and hemicellulose components of the total extractable carbohydrate all seem to be involved in the pattern of utilization and storage.

Consideration of the total amounts of carbohydrate in different parts of the tree indicates that all parts are of equal potential value as ' reserves ', and can yield about the same fraction of their total dry weights.

This year borings with a $\frac{1}{4}$ in. auger have been made at intervals into the main branches of 25-year-old Worcesters, and the shavings of wood collected separately from each centimeter depth, to find out whether all depths provide carbohydrate ' reserves '. In order to achieve the largest possible changes in these reserves some trees were deblossomed and others partially defoliated on two occasions ; fruits from these defoliated trees were smaller than those from the controls, and the carbohydrate content of the fruit will also be examined.

Different degrees of shading have also been used, as already mentioned, to affect the growth of rooted layers in pots. Analyses of the carbohydrates in the different parts of the plant are being made to assess the relative importance of stored materials and current products of photosynthesis in growth and cropping.

Photosynthetic activity can now be measured directly in terms of carbon dioxide uptake by a single apple leaf over a period of a few seconds ; the apparatus has been much improved since the last report, and valuable information has been obtained concerning the supply of air to a leaf in an assimilation chamber, by the use of model leaves.

Natural growth substances

The bulk extract of Myrobalan B shoots mentioned in last year's report has been separated into two growth promoting and one inhibiting fraction ; attempts to identify this last are being made by the Biochemistry Section. An inhibitor with a rather different action on coleoptile sections occurs in Crab C leaves, and bulk extracts have been made of this material to obtain supplies for further study.

The possibility was investigated that the amount of growth substances in a plant extract might depend upon the number of cut surfaces, but no differences were found between extracts of material with 2, 8, or 32 cut surfaces per unit length of stem.

Some further experiments were carried out on the effects of high and of low temperatures on the growth of coleoptile sections, over the whole range of concentration of β-indolylacetic acid. The results of the rather sporadic experiments on this subject over the last few years have been submitted for publication.

Many points of technique of extraction, chromatography and assay have been examined, and several improvements in apparatus introduced. The most important of these has been the construction of a new type of klinostat for the coleoptile straight growth test which accommodates 1-9 racks each holding up to 100 small specimen tubes ; this saves a great deal of time in arranging, loading and unloading the tubes used in the routine assay, and greatly simplifies tests in which repeated measurements of coleoptile sections are required.

Vegetative propagation

Collaborative work with the Pomology Section on vegetative propagation continued along the lines detailed in last year's report. As mentioned there, the critical stage in the propagation of hardwood cuttings by the controlled winter storage method is at their transference to the nursery bed. This was demonstrated this year by the ' scorch ' sustained by the foliage of Myrobalan B cuttings which had rooted up to 100 per cent during storage but which were too forward to stand up unscathed to transfer ; the other rootstock varieties used, namely Brompton, St. Julien A and Pershore plums, and Crab C, M.II, M.VII and MM.104 apples, were not damaged in this way. In all cases the best treatments resulted in at least the commercially acceptable level of 50 per cent establishment, many being much higher.

There is now particular interest in the shorter cutting, (budding the scion on to new growth) and in experiments in which the length of cutting was varied, those longer or shorter than the normal twelve inches behaved satisfactorily.

The influence of source factors on the behaviour of hardwood cuttings was investigated by pruning Crab C trees in such a way as to produce shoots of different degrees of vigour ; the beneficial effect of combined stem and root pruning on rooting was striking. In this same experiment tip cuttings were used as well as the usual basal and ' second ' cuttings, and under winter storage conditions tip cuttings were quite successful in forming roots.

The dangers of generalizations about growth substance treatment were shown in work on quince cuttings : standard growth substance ' dip ' effectively accelerated rooting as expected, but the eventual establishment of untreated cuttings may be superior.

Experimentation continued on ' mist propagation '. The main experiment, still in progress, involves two apple and two plum varieties treated factorially : with or without growth substance dip ; with or without bottom heat supplied by soil-heating cables ; and transfer from mist in autumn or spring.

Abscission

The study of the effect of thinning Sunset apples at 10, 20 or 30 days after full bloom, being carried out with the Pomology Section, was continued. The effect on fruit shedding was studied by making frequent collections of all ' drops ' (every two or three days for the first few weeks, and then weekly) ; the effect of the earliest thinning upon fruit size was very striking, and samples from all treatments are being examined for cell size and storage life by the Fruit Storage Investigation team.

Spray damage investigations

In reviewing the results of experiments during the last three seasons relating leaf damage to concentration of the spray material used (copper sulphate), the need was revealed for a more precise method of computing the effect of the spray. Such a method has now been evolved, which, while much

more laborious than those previously used, allows a more logical interpretation of the results than had previously been possible.

The effect of copper sulphate sprays used to control biennial bearing in apples continued to receive attention in collaboration with the Pomology Section, with particular reference to the subsequent development of the tree. A small trial, which will be followed up next year, was carried out on unsprayed trees to assess the effect on fruit and tree growth of removing the spur leaves which are so often damaged by the standard lime-sulphur programme.

Publications During the Year

F97 Maggs, D. H. (1957). **The growth of scions under conditions of extreme vigour.** *Ann. Bot., Lond.*, N.S., **21,** 539-54.

F99 Hancock, C. R., and Barlow, H. W. B. (1958). **Seasonal fluctuations in stem growth in the apple rootstock Crab C.** *Rep. E. Malling Res. Sta. for 1957*, 91-5.

F100 Barlow, H. W. B., and Hancock, C. R. (1958). **The effect of a summer gale on leaves of the apple rootstock Crab C.** *Rep. E. Malling Res. Sta. for 1957*, 96-100.

F101 Maggs, D. H. (1958). **A comparison of the growth patterns of two apple rootstock varieties during their first year.** *Rep. E. Malling Res. Sta. for 1957*, 101-5.

IV. BIOCHEMISTRY

A period of study at the California Institute of Technology provided the Head of Section with the opportunity to take part in some investigations concerned with respiratory pathways in plants. Particular attention was paid to the differences in the respiration of fresh and aged tissue of storage organs. The relatively sluggish respiration of freshly cut tissue exhibits well defined differences from 'normal' respiration, and striking changes occur as the tissue ages. In addition differences occur in respect of phosphate utilization. Attempts were made to trace the path of carbon in these different types of respiration using radio active tracers. The necessary extensive analytical schemes for this work were successfully accomplished. With regard to the electron transport systems involved, some interesting inhibition experiments directed attention to a possible rôle for polyphenols as electron carriers in fresh tissue, whereas they function in this capacity to a much lesser degree, if at all, in aged tissue. The experience gained in this study of respiratory pathways in plant tissue of different ages will be of value in connexion with work now being done on both apple scab and developing fruit.

This visit to California severely limited the volume of work this year on the biochemistry of host-parasite relationships. However, as part of further work on naturally occuring inhibitors of *Venturia* spp., a qualitative survey of some *Malus* species known to carry resistance factors for different races of *V. inaequalis* has revealed some striking differences among the polyphenols present ; identification of those which appear to be characteristic of some of the species is proceeding. Work on the mechanism of inhibition of *Venturia* spp. by different polyphenols and mixtures of polyphenols has been restarted.

It is well known that the glycoside phloridzin is abundant in all parts of the apple tree and a considerable quantity of sugar is combined as the glycoside. Work during the year has indicated that during the growing season, but not during dormancy, enzyme systems isolated from the tree can free the sugar from the glycoside. Further work is proceeding to establish whether phloridzin is metabolized by the tree during growth and how and when it is stored for subsequent use.

In collaboration with the Fruit Storage Investigation team a start has been made on a study of the metabolism of developing fruit of Cox's Orange Pippin receiving different cultural treatments that are known to affect keeping quality.

Publications During the Year

K106 Roach, W. A. (1958). **Lead hydroxide as a selective absorbent for certain organic constituents of plants.** *Ann. Bot., Lond.*, N.S., **22**, 127-8.

K107 ——— (1958). **A machine for disintegrating living woody shoots.** *Ann. Bot., Lond.*, N.S., **22**, 292-2.

K108 — —— (1958). **A continuous low-temperature vacuum extractor.** *Ann. Bot., Lond.*, N.S., **22**, 293-5.

V. FRUIT NUTRITION

Nutrient supply

Long-term manurial trials

To avoid further acidification of the soil in the long-term manurial trial on Plot C2, the nitrogen treatment has been changed from sulphate of ammonia at 6 cwt. per acre per year to the equivalent rate (8 cwt. per acre) of 'Nitro-chalk'. The application is made half in February and half in April.

All the experimental trees, of Cox's Orange Pippin on M.XII, were well covered in blossom but the 'set' was variable. The greatest crops were carried on the trees grassed-down in 1953. In the plots still under cultivation, the lighter crop was carried mainly on the north-east side of many of the trees, and it was noticeable in those cases that premature defoliation occurred from the fruit-bearing part of the tree; defoliation was normal on trees, mainly in grass plots, carrying heavier crops. Storage investigations (p. 39) are continuing on fruit from this trial.

The results of analyses by the N.A.A.S. Soil Chemist at Wye on soil samples taken during the year are being examined and compared with previous soil data from this trial. It is surprising that the cultivated plots receiving no nitrogen applications have a total nitrogen content, after 27 years, that does not appear to be unduly low for soils of this type at the Research Station. Although in the history of the trial definite growth and cropping responses to nitrogen applications have been obtained, the experimental trees in the no-nitrogen cultivated plots show no obvious signs of nitrogen deficiency and the nitrogen content of their leaves has not been markedly or consistently lower than that of leaves of the trees in cultivated plots to which regular applications of sulphate of ammonia have been made. In seeking an explanation of these facts, the possibility of a harmful effect of soil acidification, offsetting a potential nitrogen response, must be borne in mind: apart from this consideration, however, it appears likely that the cultivated soil is still able to supply the major part of the nitrogen requirements of the trees. Such estimates as have been made by other workers of the rate of mineralization of nitrogen in cultivated soils and of the net uptake by apple orchards suggest that such a situation is not impossible. These considerations point to the urgent need for a more complete understanding of the nitrogen balance in fruit orchards to provide a basis for the efficient use of nitrogenous fertilizers.

Field investigations on magnesium deficiency

Further large crop differences in favour of spraying with magnesium sulphate were obtained in the trial on dwarf pyramid apple trees of Edward VII on M.VII. A paper is being prepared on the first five years' results of this experiment, which also includes urea spraying.

A paper (U14) has been published describing the progress of the trials on the control of magnesium deficiency in stoolbeds of the apple rootstocks M.IV and MM.102; these are being continued. The development of symptoms was again completely prevented by 9 sprays of Epsom salt, but only partially controlled by 3 sprays, and soil applications had still less effect although a total of 28 cwt. per acre of Epsom salt over five years has now been applied in the soil treatment. The 1957 yield of MM.102 rootstocks was graded commercially to see what increase in the number of first-grade rootstocks was represented by the increase in growth already found to result from the application of 9 sprays; owing to high variability, however, the result was inconclusive. The grading will be repeated on the 1958 crop of rootstocks. As in previous years, the number of shoots affected with mildew (*Podosphaera leucotricha*) was found, at the end of July, to be less on plots receiving 9 sprays of Epsom salt than on the controls, but the difference disappeared with a general increase in mildew by the end of September.

Solution culture experiments

Some of the earlier results on the effects of iron and magnesium nutrition on apple rootstock M.VII grown in spray culture have been published (U13) and a résumé given in a bulletin (U17). The assessment of the rest of the data is almost finished. One of the results established is that good growth may be obtained by supplying iron or magnesium to the leaves of rootstocks grown without these elements in the respective nutrient supply to their roots. This treatment, however, may alter the concentration of other elements, not only in the leaves but also in other parts of the plants.

Studies on the techniques for growing apples in water culture were carried out with a view to developing a method suitable for further work on nutrition under controlled conditions. Some of the treatments designed to minimize the risk of fungal infection of the roots appeared to be effective at first, but none was completely successful over the whole season. The results emphasized the importance of adequate aeration in this type of culture.

Investigations on apple bark injury

Investigations are in progress on the causes of injuries such as those known as ' pimply bark ' and ' bark-measles ' in apple trees. Following an outbreak of this type of injury in young Lord Lambourne apple trees, an experiment has been carried out on potted trees of this variety. It is hoped to extend this work to Cox's Orange Pippin.

Soil moisture supply

The season has been noteworthy for an unusually high and uniform incidence of rain so that soil moisture supply has not seriously affected growth or fruit swelling even on the lightest textured soils. Thus, in the experiments comparing effects of different soil moisture conditions on fruit crops, treatment effects on growth and fruit size have been small but, as expected, crop yields have been markedly higher from the larger plants and these, in most cases, have been those that have been watered in previous seasons.

Thus the season has provided a useful measure of the residual effects of previous years' treatments.

Tree fruits.—The watered Laxton's Superb apple trees yielded considerably higher than the unwatered controls. The fruit from this trial has been gas-stored and will be examined for differences in storage quality next March.

The high nitrogen and irrigation treatments, applied to the Laxton's Fortune apple trees, have again given similar but non-additive effects on crop yield. Considerably greater yields have been obtained from trees either irrigated or receiving nitrogen at a high rate than from unirrigated trees receiving nitrogen at a low rate. However, the irrigation treatment in this trial was changed in 1957 from water application at a soil moisture tension of 20 cm. Hg to application at a tension of 10 cm. Hg, and there have been indications of a change in growth rate of the watered trees compared with the unirrigated trees irrespective of nitrogen treatments. This may help towards a better understanding of the inter-relationship of the effects of soil nitrogen and soil moisture on tree growth and fruiting.

An extension of the work on soil moisture effects on fruit crops has been made at Luddington Experimental Horticulture Station in a collaborative trial in which the effects of different irrigation treatments, on Cox's Orange Pippin on M.II in grass, are to be compared.

Small fruits.—The raspberry trial, started in 1956, has given very interesting crop results. Of the two varieties used in the experiment Malling Jewel gave a marketable crop of better quality and 50 per cent greater in weight than that from Malling Exploit. Either straw mulching or irrigation considerably increased yields from both varieties compared with the unirrigated clean cultivated control treatment. The better yields were the result of stronger and taller canes produced under the mulch and irrigation treatments last year.

The black currant trial on Amos Black, started last year, has shown no crop effect of the two levels of applied nitrogen but the bushes that received a late summer irrigation last year, and thereby made more shoot growth, yielded about 15 per cent more than the unwatered bushes.

Soil management studies

Papers have been published describing the effects of clean cultivation, grass, and straw mulch on the soil (U15) and indicating their possible influence on fruit crops (U16). In the field experiment on the effects of these three soil management systems on Laxton's Superb apple trees, the trees were in their ' on ' year and in general carried heavy crops. The main feature of interest in this trial is now the marked deterioration of the condition of the trees under the clean cultivation treatment. As reported last year, these trees showed poor foliage and made little growth in 1957 ; their condition appeared even worse in 1958. On the other hand, the trees in the grass plots, having recovered from the check that followed in the two or three seasons after grassing-down in 1951, are now growing and cropping well where sulphate of ammonia is applied at 6 cwt. per acre each year. During the year a change was made in the method of pruning the trees on the straw mulch plots, so that these trees are no longer directly comparable with those under other treatments ; the effect of straw mulch in greatly increasing growth had been well established, and the adoption of a lighter pruning method more appropriate to the vigour of the trees should enable their cropping potentiality to be shown.

A further extensive series of leaf samples was taken from the trees in this trial for the study being undertaken in collaboration with the Plant Analysis and Statistics Sections to elucidate the nutritional effects by investigating the relationships between concentrations of mineral elements in the tree.

A small experiment has been terminated after two years' study of the effects of differential nitrogen treatments applied both to soil and as foliar sprays on M.II rootstocks in grass and under clean cultivation. The grass was sown at the time of planting the rootstocks to ensure the maximum

' grass effect ' on the rootstocks. Adequate soil moisture has been maintained throughout the period of the experiment. Under the high nitrogen treatment extension growth of rootstocks in grass has equalled the best growth attained under clean cultivation. The results of this trial are now being summarized and interpreted.

In collaboration with the Statistics Section (p. 14), a paper (U18) has been published on the results of the first phase of the trial on the restoration of soil uniformity after grubbing a mature apple orchard. In the long-term half of the trial, where M.VII rootstocks planted in January 1957 were budded in August of that year with Cox's Orange Pippin to produce indicator trees, the ' take ' of the buds and the first year's growth of the scions were satisfactory.

Publications During the Year

U13 Delap, Anne V., and Ford, Elsie M. (1958). **Studies in the nutrition of apple rootstocks. I. Effects of deficiencies of iron and magnesium on growth.** *Ann. Bot., Lond.*, N.S., **22**, 137-58.

U14 Ford, Elsie M. (1958). **The control of magnesium deficiency in apple rootstock stoolbeds : progress report.** *Rep. E. Malling Res. Sta. for 1957*, 106-112.

U15 Goode, J. E., and White, G. C. (1958). **Soil management effects on a number of chemical and physical properties of the soil.** *Rep. E. Malling Res. Sta. for 1957*, 113-21.

U16 — · - and – —— (1958). **Soil management effects on various soil properties and their possible influence on fruit crops.** *Rep. E. Malling Res. Sta. for 1957*, 155-8.

U17 Delap, Anne V., and Ford, Elsie M. (1958). **How spray cultures assist the study of apple nutrition.** *Rep. E. Malling Res. Sta. for 1957*, 159-60.

U18 Holland, D. A., and Greenham, D. W. P. (1958). **The minimization of variability in experiments on apples planted on the site of a previous orchard. I. The effect of cultural treatments associated with three years' arable cropping.** *J. hort. Sci.*, **33**, 153-70.

VI. PLANT ANALYSIS

Studies on the mineral composition of apple plants

The results have been published of an experiment on the effect of soil moisture on the mineral composition of apple plants grown in pots. The plants grown in the moist soil contained roughly 30 per cent less nitrogen, 50 per cent more phosphorus and 15 per cent more potassium per unit of dry matter than plants grown in relatively dry soil after a period of 13 weeks, the differences being statistically highly significant. The concentrations of calcium and magnesium in the whole plant were barely affected though some interesting effects on the distribution of magnesium within the plant were noted.

Six-year-old trees of M.IX/IX and M.IX/XVI growing in the field were grubbed at monthly intervals over the year for determination of mineral elements in the whole tree and in its parts. A preliminary study of the data shows that for both rootstocks the total amount of nitrogen, per unit of dry matter, in the whole tree passes through a minimum value in March then rises, as spring growth proceeds, to a maximum in mid-June. Afterwards there is a sharp fall to a second minimum value at the end of June. Total amounts of each of the major elements absorbed month by month by the whole tree are being calculated after correcting for variation in size of the trees. This work is being followed up by means of a well-replicated pot experiment in which apple rootstocks, grown as uniformly as possible, are being sampled at monthly intervals for one year. This experiment will yield further evidence on the time and rate of uptake of elements, and their distribution within the plant.

Sand and water culture techniques have been used in three experiments this year for the purpose of providing suitable plant material for mineral composition studies. The first experiment was prompted by the chance observation that the aluminium content of various parts of apple plants may vary greatly. Apple rootstocks were grown in sand and fed with complete nutrient solutions to which were added a range of concentrations of aluminium sulphate at controlled pH levels of 4·3 and 6·5. The plants were able to tolerate up to 12·5 p.p.m. of aluminium without ill effects but suffered when the level reached 62·5 p.p.m. The plants will be analysed for content of aluminium and other elements in root, shoot and leaves.

The second sand culture experiment was designed to investigate the relation between the concentration of an element reached in various parts of the plant and the level supplied in the nutrient solution. Apple seedlings were supplied with a complete nutrient solution except that in one series nitrogen, and in another potassium, were given in logarithmically graded steps from 0·04 to 125 p.p.m.

In the water culture experiment apple rootstocks and rooted black currant cuttings were grown in a balanced nutrient solution at concentrations corresponding to osmotic pressures of 0·05, 0·5 and 5·0 atmospheres respectively in order to determine the effect on the mineral composition of the plant (see Annual Report for 1957). The method of water culture without aeration proved unsuitable except at the lowest concentration of nutrient solution ; at the highest concentration the plants died.

Leaf sampling

The results for 1957 from a leaf analysis survey of 32 orchards of Cox/M.II apple trees growing in Kent, Essex, Suffolk and Norfolk appear on p. 86. The same orchards were sampled again in July 1958 when the leaves were suffering less from mildew, hail and wind damage than in the previous year.

Cox's Orange Pippin and Jonathan growing on a range of rootstocks and on two soil types at East Malling have been sampled for the second year.

Cherries, plums, black currants and raspberries have been sampled to obtain information on the effects of leaf type and time of sampling on the mineral composition of the leaves.

In collaboration with the Statistics and Fruit Nutrition Sections, sampling has been carried out for a second year to investigate to what extent the composition of leaves sampled in various ways and at different times are correlated.

Analytical methods

The spectrographic porous cup spark method has been tested and though it is satisfactory for magnesium it appears to offer no advantage in speed and accuracy over the chemical method based on Titan Yellow. Work is in progress on a new spark method which makes use of a rotating filter paper disc ; this is giving promising results for the determination of boron, magnesium, calcium, and manganese in solutions of plant ash.

Work is continuing on the rapid arc method for direct analysis of plant ash in order to improve precision and accuracy.

During the year work has proceeded on chemical methods for the precise determination of sulphur and boron in plant material. The results of the investigation on iron await publication.

Analysis of apple fruit has given rise to some difficulty, since a uniform and reproducible state of dryness cannot be attained readily. Freeze-grinding and analysis on a fresh weight basis will be examined.

Analyses for other Sections

During the past year some 2,000 samples have been analysed for other Sections mainly in connexion with long term nutrition and orchard management trials.

Publications During the Year

V2 Mason, A. C. (1958). **The concentrations of certain nutrient elements in apple leaves taken from different positions on the shoot and at different dates through the growing season.** *J. hort. Sci.*, **33**, 128-38.

V3 ——— (1958). **The effect of soil moisture on the mineral composition of apple plants grown in pots.** *J. hort. Sci.*, **33**, 202-11.

VII. PLANT PATHOLOGY

BACTERIAL DISEASES

Bacterial canker of stone-fruits (*Pseudomonas mors-prunorum*)

Further investigation of the systemic activity of streptomycin confirmed that this antibiotic is absorbed by cherry leaves and translocated by the petioles, probably in the transpiration stream, but that its rate of translocation is too slow to permit general systemic distribution from foliar sprays. Evidence was found however that direct penetration of the antibiotic into the green tissues of the fruiting spurs might be a factor in disease control.

In a long-term field trial designed to test modified spray schedules, early autumn sprays of Bordeaux mixture, and of colloidal copper, gave appreciably better control than streptomycin. Later applications of strong Bordeaux mixture also proved superior to streptomycin, but they were less effective than earlier applications of colloidal copper. There was some evidence that where spray schedules included *spring* applications of copper bactericides the growth of the trees had been adversely affected.

In a short-term field trial three applications of Bordeaux mixture, applied in mid-August, mid-September and mid-October respectively, reduced the amount of disease by over 90 per cent compared with the unsprayed control. Cotton seed oil, applied separately or in combination with Bordeaux mixture, had no effect on the disease but prevented rapid defoliation by Bordeaux mixture sprays (p. 93).

A new investigation of the origin of stem cankers on young plum trees was begun. Inoculations of Victoria plum made early in the season in an attempt to reproduce large cankers of the kind resulting from natural infection were unsuccessful except in two instances, and in these there was evidence that the pathogen had gained access to the vascular system.

In further studies of the use of bacteriophages for the rapid identification of *Ps. mors-prunorum*, all strains of this organism, and three out of ten strains of an organism supplied from outside sources as *Pseudomonas syringae*, were lysed by these phages. None of the many saprophytic *Pseudomonas* spp. tested were susceptible. Freeing phage preparations from living bacteria by heat treatment was attempted, but the thermal inactivation point for the phages proved to be little higher than the thermal death point of the bacteria.

Fire-blight disease of pear (*Erwinia amylovora*)

A serious bacterial disease of pear which appeared in Kent and other fruit districts in 1957 and 1958 has been under investigation in liaison with the Ministry's Plant Pathology Laboratory and the N.A.A.S. and has now been identified as the 'fire-blight' disease occurring in North America and New Zealand. Its symptoms, spread in the field and the nature and identity of the causal organism were studied in detail (p. 151).

Cauliflower disease of strawberry (*Corynebacterium fascians and Aphelencoides* spp.)

A field experiment in collaboration with the Entomology Section, designed to test the ability of *C. fascians* to survive as a saprophyte in field strawberries, was completed. Plants into which a virulent strain of *C. fascians* was introduced up to 15 months previously were inoculated with eelworms (*A. ritzema-bosi*) last year to activate the bacterium. 'Cauliflowers' were recorded this year indicating the long survival of the introduced strain, and confirming that *C. fascians* can survive for prolonged periods in field strawberries in the absence of eelworms, without causing disease symptoms.

FUNGAL DISEASES

Apple and pear scab (*Venturia* spp.)

V. inaequalis was isolated from M.III and MM.109 rootstocks to provide routine sources of inoculum in the early spring for fungicide experiments with these susceptible rootstocks under glass and in the field.

Chromatographic studies with the Biochemistry Section of leaves of *Malus* spp. resistant to *V. inaequalis* have revealed marked qualitative differences between the species in polyphenolic metabolites, and the significance of these differences in relation to the various host genotypes is being studied.

Spray trials under glass of cinnamic and *o*-coumaric acid using pre-inoculated Cox shoots again showed these compounds to be active against *V. inaequalis*.

Apple storage rots (*Gloeosporium* spp.)

Post-graduate studies of apple storage rots by Dr. Z. Borecki included problems associated with the sporulation of *G. album* and *G. perennans* in culture, and the effect of the size of the orchard spore loads on the development of rots in store. Sporulation of both fungi was considerably improved by inoculating culture media with spore suspensions rather than with pieces of mycelium. The final yield of spores obtained by this means depended on the concentration of spore inoculum, the temperature of incubation and the type of medium employed. The amount of rot developing during storage from *G. perennans*, on fruits artificially inoculated at various times during the summer, was found to increase with inoculum concentration at all times of inoculation. In a parallel experiment with *G. album* no rot was observed over the corresponding period. A start was made with the problems of measuring natural spore loads in the orchard. See also "Fungicide Investigations" below.

Silver leaf disease

Work on a possible approach to the control of this disease by trunk injections with fungicides was continued.

***Verticillium* wilt diseases**

Host-parasite relationships in hops and in weed hosts

Attempts were made to develop a rapid method of differentiating progressive and fluctuating isolates of *V. albo-atrum* by direct observations of root infection after conidial inoculation. The use of detached washed roots in a plain agar conidial suspension was found impracticable because of the presence of contaminant fungi and bacteria. An alternative method using intact root systems growing in soil is now being tried.

Studies continued on the extent to which various common weeds, grasses and cereals are capable of resisting infection by *V. albo-atrum*, and the means by which such resistance is achieved. Present evidence indicates considerable variation in resistance capacity among the species which have been investigated ; none has shown complete immunity while all have exhibited defensive reactions comparable with those which have already been described in the hop. The close relevance of these observations to the work on the elimination of *Verticillium* from the soil is evident.

Abnormal outbreaks in tolerant varieties of hops

In the field much attention has been devoted to the study of severe wilt outbreaks in tolerant varieties. One such outbreak has been under observation for several years ; a second was identified in 1957. This year a widespread survey made possible through the co-operation of the Association of Growers of the New Varieties of Hops, has revealed outbreaks on ten other farms, corresponding to severe fluctuating wilt in sensitive varieties, involving the varieties OR 55, 1147, D1 and D3. So far there is no conclusive evidence that a more severe strain of the fungus is present in these sites although this possibility has been tested in previous years and again this year. Such sites may provide special environmental conditions favouring a high build-up of *Verticillium* in the soil and this possibility is being studied.

New tolerant varieties of hop.

Collaborative work with Wye College in the development of new tolerant varieties was continued as planned.

With the release in winter 1957-8 of the East Malling variety Janus (J2) to specialist commercial propagators, and the description and naming of this variety and also of the previously released varieties Density (D1) and Defender (D3) (see pages 110 and 161) this particular programme of testing and selection has been completed. Wilt-free clones of Bramling Cross (OT48) and the tolerant males B7 and 9 were also allocated to specialist propagators through the Hops Marketing Board in consultation with the Ministry.

Studies in soil relationships

Inoculation of hops with conidia from artificial cultures.—Direct observations of *V. albo-atrum* on infected plant debris in soil have shown that thin-walled spores (conidia) are produced in great

abundance and over fairly long periods of time. It was shown in 1957 that these conidia in soil are capable of infecting both sensitive and tolerant hop varieties, and that although no wilting of tolerants occurred, the rate of wilting of sensitive varieties was related to the number of conidia applied. Since the quantity of *Verticillium* added to soil can be precisely defined by the use of conidia, further experiments were carried out this year to compare the effects of three different isolates of *V. albo-atrum* in causing wilt of Fuggle N test plants. The isolates used were, (a) a ' fluctuating ' (F) strain, (b) a normal ' progressive ' (P) strain, and (c) a P strain isolated from a garden in which tolerant varieties were severely wilted. The rate of wilting caused by the conidia of both P isolates increased sharply as numbers of conidia increased, whilst that caused by F conidia increased only slightly when comparable numbers were applied. There was no difference in the effects produced by the two P isolates.

Infection of hops by conidia from natural residues.—All experiments with conidia as inocula have employed numbers of spores which, it is thought, exceed those likely to occur under natural field conditions. The infectivity of spores formed on naturally infected bine fragments in soil was tested by burying small pieces of naturally infected hop bine (*c.* 1 cm. long) in soil in small clay pots from which the drainage water was led into larger pots containing Fuggle test plants. Sufficient conidia were produced from a single bine fragment to cause 50 per cent infection and wilt, and with three bine fragments all the Fuggles were wilted. The drainage water from pots containing three bine fragments also caused infection in OM26 plants but no wilt.

Survival of V. albo-atrum in soil.—The three field trials of survival of *Verticillium* under various soil managements, noted last year, are progressing well ; the first year's results indicate that grass cover free of all broad-leaved plants may rapidly reduce the quantity of *Verticillium* in soil, but to what extent is still uncertain.

Collar rot of apple (*Phytophthora cactorum*)

Trials of the resistance of Malling, and Malling-Merton rootstocks are discussed elsewhere in this Report (p. 155). These studies have now been extended to determine the effects of *Phytophthora* infested soil on the growth of a range of rootstock varieties.

VIRUS DISEASES OF TREE FRUITS

Apple

Fruit with ' star-crack ' developed on the Cox's Orange Pippin trees inoculated in 1956 with buds from affected orchard trees, thus confirming the virus nature of this disease. Reports by advisory officers show that the disease is widespread and affects many varieties.

Buds from symptomless trees of Lord Lambourne were found to be carrying the virus responsible for the stem pitting disease associated in America with Virginia Crab stocks.

Pear

The compatible strain of Williams' Bon Chrétien, forming strong unions with Quince A rootstocks, was successfully heat treated for vein yellows infection and healthy material was propagated.

To obtain healthy material of Packham's Triumph, scionwood was imported from South Africa but all proved to be virus-infected ; the best clone will now be heat treated.

Further work on quince indicators revealed two additional viruses latent in pear.

Cherry

Dr. R. M. Gilmer (p. xix) made a valuable contribution to our knowledge of the behaviour of *Prunus* viruses in herbaceous hosts. The viruses probably causing necrotic ring spot, sour cherry yellows, leaf roll, ring mottle and rasp leaf were found to induce specific symptoms on herbaceous hosts including cucumber, squash and tobacco. Further work is necessary to identify with certainty the viruses concerned.

In the field trial planted in 1953, trees of Early Rivers, Napoleon and Merton Bigarreau sweet cherries with latent virus infection continued to yield less fruit than virus-free trees. The crop of healthy trees of Early Rivers was for instance threefold that of symptomless trees carrying the necrotic ring spot–sour cherry yellows complex. A similar reduction occurred in 30-year-old trees infected four years ago.

Plum

So far heat treatment appears to have eliminated viruses from Common Plum, Marianna, Victoria, Ontario and Ruth Gestetter.

Virus-tested sources of scion varieties for the Mother Tree Scheme

The selection, testing, heat treatment and propagation of material for distribution in the Mother Tree Scheme continued. The discovery of ' new ' viruses, such as that of stem pitting in apples, has necessitated the re-examination of our material and yet further improvement in health standards may therefore prove possible.

VIRUS DISEASES OF SOFT FRUITS

Strawberry

Two groups of viruses were investigated : those transmitted (a) by leafhoppers and associated with green petal disease, and (b) by unknown means in the soil.

The leafhopper *Aphrodes bicinctus* was shown to be capable of infecting strawberry plants with green petal virus ; it has been found breeding on strawberry in the field. This species may therefore be the one against which control measures should be aimed.

Soil-borne viruses were investigated and tentatively identified by a post-graduate student, Mr. Asharfi Jha. Most of the viruses transmitted by sap inoculation to petunia and other herbaceous hosts were strains of the raspberry yellow dwarf virus, and this was found to be responsible for strawberry mosaic disease in Cheddar and Kent.

Strawberry Nuclear Stocks

Fourteen varieties were again propagated for the 1958-9 issue to the Nuclear Stock Association, and plants of Huxley, Early Cambridge and Cambridge Favourite were given further heat treatment to remove their mild virus infection.

Loganberry and blackberry

One additional loganberry selection (New Zealand) and two thornless loganberry sports were indexed and appear to be virus-free. A field trial was planted to assess the effects of the virus isolated from ' degenerate ' loganberry. Progress was made in initial studies of other diseases of possible virus origin in loganberry, and in Himalaya Giant and Bedford Giant blackberries.

VIRUS DISEASES OF HOPS

Nettlehead

No confirmation was obtained this year of the previously reported results suggesting that nettlehead may be caused by a virus occurring naturally in clover.

The possibility of soil transmission was also investigated ; hop plants grown for two years in soil taken from around nettlehead infected plants have not yet shown symptoms. Furthermore, in a field trial of 65 hops established as replants during the last seven years following grubbed nettlehead infected plants, none have yet become infected. Additional to this negative evidence, however, an unidentified virus was isolated from soils in which hop plants, including those affected by nettlehead, are growing. The significance of this virus has yet to be established.

Split leaf blotch

Of six clones of Fuggle seedlings graft inoculated with split leaf blotch virus a few plants developed symptoms, and the series will be recorded again next year.

Mosaic

No transmissions of mosaic by the mites used in last year's tests were confirmed.

Two types of mosaic were identified, severe and mild, caused by differing strains of the mosaic virus and distinguished by the lethal action of the latter on Golding hops.

FUNGICIDE INVESTIGATIONS

Concentrate sprays

Experiments concerned with the effects on apple scab and apple mildew of variations in the droplet size and volume of lime-sulphur sprays were continued during 1958 in collaboration with the National Institute of Agricultural Engineering. Data from 1957 indicated no marked effects from either variable in spraying at fixed dosage per acre.

Systemic fungicides

Griseofulvin, cinnamic acid and *o*-coumaric acid were compared as spray concentrates with undiluted lime-sulphur, using M.III rootstocks artificially inoculated in the field with conidial suspensions of *V. inaequalis*. In May best control was given by lime-sulphur when the sprays were applied the day after inoculation, but none gave any control of scab resulting from inoculations made three weeks later.

Comparison of protectant and curative spraying in apple scab control

A trial was started in a plantation of Cox's to compare the normal protective spray schedule with post infection or curative sprays applied on the basis of ' Mills periods '.

Apple mildew

An account of an experiment completed this year on unworked M.III rootstocks in the field, to test the action of early spring sprays against overwintered bud infections, appears elsewhere in this Report (p. 103).

Greenhouse experiments on apple scab infection and control

Experiments on potted MM.109 rootstocks, as previously described, were continued. The factors investigated included the relative efficiency of different forms of inoculum, the relationship between infection and duration of leaf wetness, and the effects of discontinuous periods of leaf wetness. The technique was further used to compare the protective and eradicant properties of various fungicides, e.g. lime-sulphur and organic mercury compounds.

Apple storage rots (*Gloeosporium* spp.)

An account of a spray experiment completed last year at Bassett's Farm, Horsmonden appears on page 106. Another trial, started at the Research Station in 1957, involves a comparison of single spray applications of captan or cinnamic acid in September, with a fruit dip in cinnamic acid after harvest. This year it was found that cinnamic acid had reduced infection whether used as a spray or dip, but that captan had been the more effective spray.

Spore dispersal and meteorological conditions in relation to apple scab infection

Co-operation continued as in 1957 with Dr. J. M. Hirst (Rothamsted Experimental Station) and the N.A.A.S., in a country-wide survey.

Publications During the Year

C393 Kirkham, D. S. (1957). **The significance of polyphenolic metabolites of apple and pear in the host relations of *Venturia inaequalis* and *Venturia pirina*.** *J. gen Microbiol.*, **17**, 491-504.

C394 Frazier, N. W., and Posnette, A. F. (1957). **Transmission and host-range studies of strawberry green-petal virus.** *Ann. appl. Biol.*, **45**, 580-8.

C395 Posnette, A. F., and Ellenberger, Christina E. (1957). **Bark-split—a virus disease of plums.** *Ann. appl. Biol.*, **45**, 573-9.

C396 Moore, M. H. (1958). **Concentrate spraying—fungicidal aspects.** *J. Soc. chem. Ind., Lond.*, Mono. No. 2, 3-14.

C397 Crosse, J. E., and Hingorani, M. K. (1958). **A method of isolating *Ps. mors. prunorum* phages from soil.** *Nature, Lond.*, **181**, 60-1.

C398 Posnette, A. F., and Cropley, R. (1958). **A little cherry disease in England.** *Rep. E. Malling Res. Sta. for 1957*, 122-3.

C399 Cropley, R. (1958). **Erratic transmission of strawberry viruses by grafting excised leaves.** *Rep. E. Malling Res. Sta. for 1957*, 124-5.

C400 Sewell, G. W. F., and Wilson, J. F. (1958). **Weed hosts of the ' Progressive ' hop strain of *Verticillium albo-atrum* Reinke and Berth.** *Rep. E. Malling Res. Sta. for 1957*, 126-8.

C401 Legg, J. T., and Ormerod, P. J. (1958). **The nickel content of hop plants with reference to nettlehead symptoms.** *Rep. E. Malling Res. Sta. for 1957*, 129-32.

C402 Harris, R. V. (1958). **Progress in research on *Verticillium* wilt and virus diseases in hops in 1957.** *Rep. E. Malling Res. Sta. for 1957*, 161-3.

C403 MOORE, M. H. (1958). **The incidence and control of cane spot (*Elsinoë veneta* (Burkh.) Jenk.) on Loganberry.** *J. hort. Sci.*, **33**, 96-107.

C404 ——— (1958). **The release of ascospores of apple scab by dew.** *Plant Path.*, **7**, 4-5.

C405 POSNETTE, A. F. (1958). **The spread and control of virus diseases of fruit trees.** *Sci. Hort.*, **13**, 87-9.

C406 TALBOYS, P. W. (1958). **Some mechanisms contributing to *Verticillium*-resistance in the hop root.** *Trans. Brit. mycol. Soc.*, **41**, 227-41.

C407 ——— (1958). **Degradation of cellulose by *Verticillium albo-atrum*.** *Trans. Brit. mycol. Soc.*, **41**, 242-8.

C408 ——— (1958). **Association of tylosis and hyperplasia of the xylem with vascular invasion of the hop by *Verticillium albo-atrum*.** *Trans. Brit. mycol. Soc.*, **41**, 249-60.

C409 POSNETTE, A. F. (1958). **Two virus diseases of apples in America.** *Grower*, **49**, 1479 (Under different title).

C410 ———, and MILLIKAN, D. F. (1958). **Some virus-like disorders of pome fruit trees in Missouri.** *Plant Dis. Reptr.*, **42**, 200-1.

C411 CROSSE, J. E., and GARRETT, CONSTANCE M. E. (1958). **Experiments on the movement of streptomycin in cherry trees.** *Ann appl. Biol.*, **46**, 310-20.

C418 FRAZIER, N. W., and POSNETTE, A. F. (1958). **Relationships of the strawberry viruses of England and California.** *Hilgardia*, **27**, (17), 455-513.

C420 POSNETTE, A. F. (1958). **Virus diseases of fruit trees.** *American Nurseryman*, **107**, 7, 15 and 63-5.

C421 SEWELL, G. W. F., and GLASSCOCK, H. H. (1958). ***Verticillium* wilt of apple.** *Plant Path.*, **7**, 76.

VIII. ENTOMOLOGY

Tree fruits

Woolly aphid : resistant apple seedlings

Seedlings of Court Pendu Plat × Northern Spy, found to be resistant to woolly aphid last year, maintained their resistance following inoculations made throughout the spring and summer. Similar crosses tested in 1955 and 1956 also gave a proportion of plants resistant to aphid attack. Of 220 seedlings of Cox's Orange Pippin × Northern Spy that received their initial tests, 52 per cent proved resistant. Of 57 seedlings of Crawley Beauty × Irish Peach inoculated with aphids, 100 per cent were susceptible. Both Crawley Beauty and Irish Peach are resistant to the aphid under field conditions. The causes of resistance are being studied in collaboration with the Pomology Section.

The alate forms of the woolly aphid were unusually numerous in the insectary and in the field this autumn ; in most years the winged form is scarce.

Natural control of orchard pests

The experiment to assess the relative effect of predatory insects and mites on phytophagous mite populations was continued. Insect predators were removed from the trees by hand and although complete removal is impossible some success was achieved in obtaining different levels, and these differences were reflected in the fruit tree red spider mite populations. Different levels of *Typhlodromus tiliae* Oudms. have also resulted in considerable differences in numbers of this mite and the interaction between insects and *Typhlodromus* is being studied.

Insectary experiments on *Prunus* seedlings have been successfully carried out to compare the response of *T. tiliae* Oudms. and *T. finlandicus* (Oudms.) to different population levels of fruit tree red spider mite and *Vasates fockeui* (Nalepa).

At the Essex Institute of Agriculture a new experiment was carried out jointly with the Plant Protective Chemistry Section in the Worcester orchard. A single application of amiton practically eliminated the mites and the residual toxicity was considerable. Two June applications of chlorbenside were used as a standard of comparison, this chemical having given excellent control for the past three years in this orchard. This year, however, control by the standard June applications of chlorbenside was negligible, and a third application at 0·05 per cent in late July also proved inadequate, with the result that bronzing was severe by the end of August.

Observations on field populations of *Anthocoris nemorum* L. and on details of its life-history are in progress.

The study of the integrated action of insecticides and fungicides on the fruit tree red spider mite and its predators as well as leafhoppers was continued for its sixth successive year. Predators were sufficiently abundant in 1958 to maintain control of the mite. In general control was most effective with treatments which interfered least with the predators.

A subsidiary experiment started in 1957 to elucidate further the interaction of predator and prey was continued.

Studies were also made on the development and fertility of *Psallus ambiguus* (Fall.) under field insectary conditions, and a laboratory investigation was conducted on the influence of lime-sulphur on this insect.

Biology of aphids

Work on the aphids of *Prunus* spp. was continued.

Evaluation of pre-blossom apple insecticides

Trials carried out in collaboration with the Plant Protective Chemistry Section showed that the performance of selected organophosphorus compounds compared favourably with DDT-BHC against the apple-grass aphid, but control of apple sucker was variable. Assessment of toxicity against winter moth caterpillars under orchard conditions was not possible because populations were too low.

Codling moth and other orchard tortricids

Results of the 1956 and 1957 field trials for codling moth control indicate that ryania and diazinon are intermediate in effect between lead arsenate and DDT. Like DDT, however, both ryania and diazinon encourage the build-up of the fruit tree red spider mite. In 1958 field trials with the insecticides *O*-1-naphthyl *N*-methylcarbamate and an organophosphorus compound were carried out in collaboration with the Plant Protective Chemistry Section.

Further observations have been made on the time of emergence of codling moths from overwintering sites in cages for comparison with data on their emergence in the field. The incidence of parasitism of overwintering larvae has also been recorded.

The mercury vapour light trap has been in use for eight seasons to provide data on the flight period of codling moth and other orchard tortricids. The reduction of the population of the summer fruit tortricid, *Adoxophyes orana* (F.R.) observed in 1957 was not maintained in 1958.

Leafhoppers

The life-histories of *Typhlocybid* leafhoppers on apple have been studied for the third successive year, and further observations have been made on the direct and second-year effects of codling moth spray treatments on their populations.

Work is continuing in collaboration with the Plant Pathology Section on the known or suspected leafhopper vectors of the green petal and allied viruses. The longevity and reproductive potential of *Euscelis plebius* (Fall.) has been studied in the laboratory. A population of *Leopotettix dilutior* (Kirschb.) has been found that is naturally infected with a virus thought to be in the yellows group.

A preliminary field trial for the control of green petal disease in strawberry is being undertaken in co-operation with the Pomology Section.

Studies of the life-histories of leafhopper species of the genus *Macropsis* which feed on *Rubus* have continued. The effect of chemical control combined with roguing of virus-infected plants on the incidence of virus is being investigated on two farms.

Broybia mite investigations

Studies of the life-histories of the *Bryobia* mites found on apple, pear, gooseberry and ivy have continued. The species found on apple is regarded as the same race or strain as that on pear, but the species found on gooseberry is probably distinct from that on top fruit. Mites transferred from ivy to apple and *vice versa* died before reaching the adult stage. In Kent the strain found on apple is parthenogenetic, and no males of this strain have yet been found.

Study of phytophagous and predacious mites

Eriophyid mites received from various sources have been identified. A number of predacious mites are being studied, particularly those associated with apple, and methods are being worked out for breeding them in the laboratory.

Insect rearing in the laboratory

Further progress has been made in the rearing of the coccinellid, *Synharmonia conglobata* (L.) and of the summer fruit tortricid, *Adoxophyes orana* (F.R.). A culture of the fruit fly, *Drosophila melanogaster* Meigen was used in bio-assay work by the Plant Protective Chemistry Section, and a start has been made in the rearing of the codling moth.

Laboratory testing of insecticides

Techniques for the exposure of certain species of insects to insecticidal deposits on foliage have been worked out in conjunction with the Plant Protective Chemistry Section. These techniques have been applied in preliminary experiments on the effect on beneficial insects of insecticides used for codling moth control. Experiments have also been carried out on the persistence of the biological activity of spray deposits on apples.

Soft fruits

Raspberry aphid : testing Rubus species

The testing of raspberry seedlings for resistance to the raspberry aphid *Amphorophora rubi* (Kalt.) has continued in collaboration with the Pomology Section. Following the discovery of strains of the aphid capable of overcoming the resistance conferred by certain of the genes used in raspberry breeding, the maintenance of pure stocks of these strains has become necessary. Living material of *A. rubi* collected in many different localities in England and Scotland, has been tested to determine the distribution and abundance of the different strains.

Control of black currant gall mite

Further field trials have been carried out in conjunction with the Plant Protective Chemistry Section to assess the efficacy of endrin and of relatively high concentrations of lime-sulphur, applied at various stages of growth up to the blossom period, for mite control.

Strawberry seed beetle and other ground beetles

Comparisons have been made of the larval populations of the strawberry seed beetle in both weedy and clean cultivated ground, and also in strawberries, and the preference of the younger larvae for the weedy conditions has been clearly established. Population sampling for this and other species was carried out in strawberries throughout the season and traps were set in the same plot for comparison. The first season's results showed that all the beetles that damaged the fruits came to the beds from outside sources.

Laboratory tests on the relative toxicity in the soil of aldrin, dieldrin and endrin to the strawberry seed beetle have shown that endrin is of low toxicity while aldrin is superior to dieldrin. Field tests in which residues of these chemicals on the fruit of strawberry plants and in the soil beneath the plants were measured at intervals showed results similar to those of the laboratory trials. In another trial comparing pre-blossom and pre-strawing applications of aldrin and dieldrin, both materials were found to be very persistent in the soil ; aldrin applied pre-blossom left no residues on the fruit but left residues in the soil that were toxic to the beetles throughout the fruiting period.

Soil migratory nematodes

Previous observations on the improvement in the growth of apples brought about by application of gentle heat (60° C. for 30-40 minutes) to old apple soils have indicated the complex nature of the inhibitory factors present in the soil. Soil migratory nematodes are clearly one of these factors, and evaluation of their role remains the prime objective of the present nematological programme. Controlled inoculation experiments are needed to provide this information and efforts to develop nematode culture and inoculation techniques have continued. Attention has been concentrated on *Pratylenchus penetrans* (Cobb), the most universal endoparasite of fruit plant roots, and on apple, the most widespread fruit host. Inoculation of potted seedlings has not given consistent results, but often, especially in large pots plunged in the field, a slow multiplication has continued for periods of up to two years. Other hosts have given similar results and even the most promising, a Canadian vetch, has brought about a multiplication rate far slower than that obtained in Canada with *P. penetrans* from peach. In the past, small-scale culture techniques have given better results and a comparison of variations of these with pot techniques is in progress.

A full analysis of the inhibitory factors present in old apple soil is beyond the scope of this programme, but their source has been investigated in a replicated pot experiment using pairs of similar soils, comparing old apple soils and soils not previously planted with apples. In two pairs out of three, gentle heat brought about greatly improved apple growth in the apple soils but not in the others. The gentle heat has eliminated migratory nematodes in all soils, but in one pair the natural population of *Pratylenchus* spp. was high and in the other it was very low.

Nematological surveys in relation to field problems have produced three cases worthy of note. In the first, strawberries failing and dying in patches in a light sandy soil were found to be heavily attacked by *P. penetrans*, and the distribution of this species corresponded well with the severity of damage in the field. In the second, numbers of *Xiphinema index* Thorne and Allen were recovered from the soil around the roots of strawberry plants infected with raspberry yellow dwarf virus. In the third, the soil around black currant stock plants that showed a marked reduction of fine roots was found to contain very high populations of two species of *Rotylenchus*. No causal relationship has been established in any of these cases, but strawberry inoculation experiments are in progress. The Seinhorst elutriator, modified to suit British soils, has now been adopted for all routine and experimental soil examinations, and yields of nematodes are now 2-4 times those obtained in the past with other techniques.

Leaf and bud nematodes (*Aphelenchoides* spp.)

The field experiment on the infestation of strawberry plants by soil-borne *A. ritzema-bosi* (Schwarz) has been concluded. The slow infestation from natural sources has continued steadily and plants set in uninoculated soil $4\frac{1}{2}$ years ago are now as heavily infested as those set in inoculated soil.

The collaborative field experiment with the Plant Pathology Section on the survival of *Corynebacterium fascians* (Tilford) Dowson on strawberries in the absence of *A. ritzema-bosi* has also been completed. It has confirmed and extended the conclusion, drawn from an earlier experiment, that selected strains of this bacterium can survive thus for long periods without loss of virulence.

Publications During the Year

D310 Dicker, G. H. L., and Tew, R. P. (1957). **Some experiments to investigate the control of apple sawfly, *Hoplocampa testudinea* (Klug), by concentrate sprays.** J. hort. Sci., **32**, 254-64.

D311 CHANT, D. A. (1958). Immature and adult stages of some British *Phytoseiidae* Berl., 1916 (Acarina). *J. Linn. Soc. (Zool.)*, **43**, 599-643.

D312 PITCHER, R. S. (1957). A critical review of current techniques for the study of migratory root nematodes as etiological agents. *Nematologica*, **2**, Suppl., 413-4238.

D313 MASSEE, A. M. (1958) Notes on some interesting insects observed in 1957. *Rep. E. Malling Res. Sta. for 1957*, 133-35.

D314 PITCHER, R. S. (1958). The biology of the black currant leaf midge *Dasyneura tetensi* (Rubs.) in relation to the planning of control measures. *Rep. E. Malling Res. Sta. for* 1957, 136-39.

D315 MUIR, R. C. (1958). On the application of the capture-recapture method to an orchard population of *Blepharidoperus angulatus* (Fall.) (Hemiptera-Heteroptera, Miridae). *Rep. E. Malling Res. Sta. for 1957*, 140-47.

D316 COLLYER, E. (1958). Some insectary experiments with predacious mites to determine their effect on the development of *Metatetranychus ulmi* (Koch) populations. *Ent. exp. and appl.*, **1**, 138-46.

D320 PITCHER, R. S., and CROSSE, J. E. (1958). Studies in the relationship of eelworms to certain plant diseases. II. Further analysis of the strawberry cauliflower disease complex. *Nematologica*, **3**, 244-56.

IX. PLANT PROTECTIVE CHEMISTRY

Analytical methods

Further refinement of the chemical methods for determining microgram quantities of aldrin, dieldrin, and endrin has been achieved, and satisfactory procedures have been developed for malathion and for a new type of insecticide of high activity and low mammalian toxicity, *O*-1-naphthyl *N* methylcarbamate. The application of the Gutzeit method for arsenic to residues on apples has been re-studied and more work has been carried out on the use of the well-known Schechter-Haller DDT method for a number of DDT analogues. In collaboration with the Entomology Section, a bio-assay technique using *Drosophila melanogaster* has been developed and used for the measurement of sub-microgram quantities of dieldrin, endrin, and dimethyl 1-methoxycarbonyl-2-methylvinyl phosphate ; it may prove possible to use this method with other insecticides.

As forecast in last year's Report, residue methods have been developed for certain fungicides ; sulphur, both poly sulphide and elemental, mercury, in organic combination, DNOP, as crotonate or free phenol, and captan can now all be determined in microgram quantities.

Use of insecticides on top fruit

Pre-blossom application

Two of the newer systemic organophosphorus compounds and the new carbamate have been compared, in collaboration with the Entomology Section, with a standard BHC-DDT mixture for control of pests present at or soon after bud-burst. All were effective against aphid, but only one against sucker. Caterpillar was not present in sufficient quantity to provide a result.

The amount of insecticide deposited on a bud presumably varies with its stage of development. Insecticides applied to several varieties at a comparable stage of development have given similar amounts per bud regardless of variety, whereas applications made on the *same date* to four commercial varieties led to deposits differing by as much as 4 : 1. It is not surprising, therefore, if, in a mixed plantation, control of a pest may be achieved on one variety and not on another given identical treatment.

Codling moth

Although ryania and the organophosphorus insecticide, diazinon, gave better control than did lead arsenate in 1956 and 1957, both seemed to lead to increases in numbers of the fruit tree red spider mite. Trials were therefore made in 1958, in collaboration with the Entomology Section, of the new carbamate referred to above, and of another new organophosphorus compound.

The persistence (half-life) of DDT, lead arsenate and the non-phosphorus insecticide on foliage were found (for the trial in question) to be nine, nineteen, and four days, respectively.

Two applications, at normal rates and timing, of DDT or lead arsenate led to harvest residues of DDT well below the U.S.A. tolerance of 7 p.p.m., but of arsenic rather above 1 p.p.m. A similar residue of arsenic was found on Beauty of Bath from Farm plots, even though lead arsenate had only been used for the earlier of two sprays, but later-picked varieties had residues below 1 p.p.m.

Fruit tree red spider mite

The presence of a considerable winter egg population in the Worcester Pearmain orchard at the Essex Institute of Agriculture, Writtle, made possible a trial, in collaboration with the Entomology Section, in which chlorbenside, applied to the entire orchard in 1956 and 1957, was compared for overall effects with a new organophosphorus acaricide, amiton. The latter, applied once as the hydrogen oxalate, gave a very satisfactory result. Chlorbenside, however, although applied twice at the recommended rate and later again at double this rate, failed to hold the pest which caused some bronzing. Chemical analyses showed normal deposition and persistence of chlorbenside, and the conclusion was drawn that this trial provided the first unassailable evidence of mites in an English orchard that are not susceptible to this acaricide. As this phenomenon is already familar in many fruit growing areas in other parts of the world, and extends in one place or another to most, if not all acaricides at present known, it is clearly of great importance to the fruit industry (see p. 131).

Use of insecticides on soft fruit

Strawberry

Laboratory and field experiments, in collaboration with the Entomology Section, have continued on the use of aldrin, dieldrin or endrin for control of seed-eating beetles. Endrin proved definitely

inferior to aldrin or dieldrin, and aldrin would appear to be the insecticide of choice. As it appears that pre-blossom applications may afford adequate protection of the fruit, it is of interest that pre-blossom sprays of dieldrin led to very low residues in the first pick and none in the main pick ; aldrin applied at the same time could not be found in fruit at all. Application of either insecticide just before strawing of the bed led to higher but not alarming residues in the fruit.

Black currants

Earlier application of a weaker spray of endrin than the timing and concentration used in 1957 still led to residues on fruit in excess of 1 p.p.m., except when the application was made at the grape-stage. There is good reason to believe that endrin on picked fruits is not present in juice expressed from those fruits.

Raspberry

The potential value of malathion for control of raspberry beetle on *Rubus* spp. raised the question of harvest residues. Spraying with 0·1 per cent malathion (emulsifiable concentrate) led to a residue on raspberries of just under 1 p.p.m. a week later.

Mode of action study

A preliminary study has been made on the evolution of hydrogen sulphide during the drying of lime-sulphur deposited on leaves. It has been shown, in collaboration with the Entomology Section, that gaseous emanation from lime-sulphur deposits is necessary before certain beneficial species are killed, and some idea of the threshold amount of hydrogen sulphide required has been obtained.

Fungicides

Glass-slide method

One of the major problems likely to cause variation between slides, and even between circles on the same slide, has always been associated with cleaning the slides. The use of ' cleaning-mixture ' (chromic acid) is well-known to leave glass-ware in a state far from inert to biological systems, and the procedure hitherto employed, using a strong detergent and (when necessary) a mild abrasive, was suspected to be uncertain. Fortunately, a new cleaning process, based on permanganic acid, has been reported, and this has given slides of exceptional cleanliness, as shown by the ease of spreading of copper sulphate solutions (5-50 p.p.m.) containing no wetting agent. When spore-suspensions containing suitable concentrations of nutrients as well as the toxicant under test, were pipetted on to such slides, variability between duplicate counts on a circle, between circles, or between slides was reduced to less than the calculated expectation. Variability was, however, much higher if copper sulphate, for example, was applied to the circles first, and the spore-suspension added later to the dried deposits.

Powdery mildews

A full season's work (12 weekly tests) comparing chemicals on apple rootstocks was achieved for the first time ; this was in part due to favourable weather for greenhouse work, although the one hot spell, in early July, reduced the efficiency of one test and seriously interfered with spore-production. To test the extent of this problem, rootstocks were infected as usual and, twenty-four hours later, subjected to a temperature of 98-99° F. for four hours ; the incidence of disease recorded a week later was only half that on unheated control plants.

The season was extended at both ends by using seedlings of Plumage Archer barley in 2 in. pots, and a small infection tower ; the advantages, besides the possibility of working when apple cannot be used in the present accomodation, include the fact that spores can be collected and weighed, giving some control over spore-load from one test to another, and the possibility of conducting two tests per week in the same accommodation. Results obtained so far show that the two species of powdery mildew respond to toxicants in a very similar way, although the susceptibilities of the apple stocks used (M.III) and of the barley variety to chemicals do not always run parallel.

The increases in mildew attack achieved in 1957 on barley seedlings pre-dipped in dilute solutions of certain surfactants were not obtained in a test on apple stocks, nor in a further barley test in 1958. The increases in 1957 were all associated with surfactants that were poor wetting agents ; good wetting agents have not increased attack in any test, and would not seem to constitute any danger on that count.

It has been confirmed, on both apple and barley, that the free phenol, DNOP, is as effective in preventing mildew attack as is the ester DNOPC, and that crotonic acid is unlikely to play an important

role in mildew control. DNOP is toxic to barley seedlings at concentrations effective against mildew ; the ester, DNOPC, at equimolar concentration was scarcely less toxic. A report on this work has been published.

It has been found that the isomer with a straight carbon chain, 2 : 4-dinitro-6-*n*-octylphenol, and that with the cyclic alkyl substituent, 2 : 4-dinitro-6-*cyclo*-octylphenol, are very nearly as toxic as DNOP to both mildew species, but that the *cyclo*-octyl compound is decidedly more phytotoxic ; dinex, on the other hand had only slight toxicity even to barley, but control of mildew was much inferior. Certain compounds recently claimed as effective against cucumber powdery mildew were not found of any promise against apple or barley mildew ; certain antibiotics, actidione and derivatives and P.189, were fairly active but not all were safe.

Chemical analyses of DNOP deposits on apple leaves showed that much smaller loss occurred in 48 hours in the greenhouse than from an identical level on trees in the open. This is desirable as plants are inoculated 24 hours after dipping in toxicant preparations.

Experiments using ' Gregory ' electrolytic elements showed that the relative humidity in the large tower quickly reached 100 per cent when 100 stocks were enclosed. Subsequently, trials with the same equipment in the small tower, showed that high atmospheric humidity is not essential for infection or the initial development of powdery mildew on apple in the greenhouse and, probably, not in the orchard.

The field trial of low rates of DNOPC, with and without methyl cellulose, was continued for a second year. Disease levels have so far been low on all treatments. Chemical analyses indicated a rather small increase in initial deposit and persistence of DNOPC where the methyl cellulose was added ; the rate of loss of DNOPC was high in either case. Captan proved to be three to four times as persistent in the same trial.

Low volume spraying

A modified method for analysis of sulphur deposits has been used to provide the Plant Pathology Section with information regarding the level of deposits obtained in work with low volume applications of lime-sulphur.

Phytoxicity

A trial has been set up on three varieties on M.VII to study the interaction of type of fungicide with order of application. The trees are now six years old and in cropping. No untoward effects have been seen in the first year of the trial.

Trials with a 70 per cent wettable powder based on *n*-dodecylguanidine acetate have been carried out on nine apple varieties on M.VII, in comparison with normal lime-sulphur or captan schedules, at 0·07 or 0·1 per cent active ingredient. Some extra russeting was seen on a few varieties, especially Sunset on which ' frost-rings ' were very marked at harvest.

Some loss of crop was found in trials on two varieties on M.VII with *O*-1-naphthyl *N*-methylcarbamate, 50 per cent wettable powder, applied twice post-blossom, either alone or in conjunction with chlorbenside (20 per cent wettable powder) or with colloidal sulphur and captan.

The trial of copper (Bordeaux mixture), mercury (PMC), and arsenic (lead arsenate and zinc fluoroarsenate plus weak lime-sulphur) was carried on for a final (seventh) year on two apple varieties.

A trial was begun on three varieties of pears on Quince A comparing a sulphur schedule (three applications) with two post-blossom applications of PMC. Half of the PMC-treated trees are being left to natural weathering and the rest are re-wetted, if necessary, on five consecutive evenings after each application of PMC ; no crop difference was caused by this procedure and no difference in persistence was detected chemically, in the first season.

Applications of lime-sulphur at high *versus* low volume were again made to two varieties of black currant, but rather later than the grape-stage ; no crop losses were detected.

A straight comparison of lime-sulphur and DNOPC, 25 per cent wettable powder, was made, pre- and post-blossom, on two varieties of gooseberry ; no damage or crop loss was detected.

Experiments have been continued on the intake by leaves of copper from Bordeaux mixture deposits, but the major effort has been put into work on the intake of magnesium. It is however, desirable to have information about the intake of another divalent metal that is much less toxic, if a full understanding of the process in respect to copper is to be gained. Study of magnesium intake through leaves has, moreover, obvious potential value for plant nutritional investigations. It has been possible to develop an analytical method for this metal that is of sufficient accuracy and yet enables large numbers of samples to be handled quickly. Early experiments with detached leaves showed points of similarity between intake of copper and of magnesium. Rapid intake by immersed leaves occurred in the field, but when the normal spraying technique was used, the great variability

in the natural magnesium content of leaves made it impossible to show that any magnesium was take in. However, studies with untreated leaves of low natural magnesium content led to the selectio of conditions under which it was possible to show that the magnesium content of leaves can sometime be usefully increased within an hour of applying a magnesium salt to the leaves. It was als found that magnesium sulphate, though the cheapest salt, was by no means the most efficient fo raising the leaf content ; indeed adequate intake was achieved from the chloride or nitrate on certai occasions when no intake could be demonstrated from the sulphate.

Publications During the Year

Q95 Kirby, A. H. M., and Bennett, Margery (1958). **Further phytotoxity studies with phenylmer curic chloride on Conference pear.** *Rep. E. Malling Res. Sta. for 1957*, 148-51.

Q96 ——— and ——— (1958). **Phytotoxity trials with acaricides on black currant and plum.** *Rep E. Malling Res. Sta. for 1957*, 152-4.

X. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

Apple manurial trial

Cox's Orange Pippin apples from the long term manurial trial were again stored at 32° F. and 37° F. as in previous years. The overall level of *Gloeosporium* rotting was higher this year but the effect of sward in reducing the percentage wastage due to *Gloeosporium* rots and to low temperature breakdown was again observed. Nitrogen applications increased the losses from rotting, especially in the presence of applied phosphorus, but in clean cultivation nitrogen reduced breakdown. Applied potash decreased wastage from breakdown.

Skin thickness was measured in fruit from two extreme treatments, sward without nitrogen and arable with nitrogen. No apparent differences were found in the thickness of either the cuticle or the tangential cell walls in the skin.

Chemical analyses of the fruits were made at the Ditton Laboratory, and of the skin waxes of fruits from certain treatments at Long Ashton Research Station. Fruitlets and fruit were sent throughout the growing and storage season to Leeds University for the study of cell-wall constituents.

Time of picking

Storage comparisons at 32° F. and 37° F. were made on Cox's Orange Pippins picked at the normal time, a fortnight before, and a fortnight after respectively. Wastage through *Gloeosporium* rots was least with the earliest pick and increased progressively with the later picks, but low temperature breakdown was least with the latest pick. Under the conditions of the experiment, however, the latest pick was in store for the shortest time owing to the examinations being made on the same dates for all samples. Full chemical analyses have been made on these fruits at Ditton Laboratory.

Commercial samples

Samples of Cox's Orange Pippin from the same nine orchards in Kent, Sussex, and Essex as in 1955 and 1956 were stored at 32° F. and 37° F. Additional samples were included from two orchards in Suffolk. The fruit from some of these orchards has been behaving consistently from year to year, from others there has been little consistency, and from a few there has been a marked improvement in storage quality, probably as a result of modifications in the orchard management. Detailed chemical analyses were made on all these samples at Ditton Laboratory.

Survey of commercial fruit

A large number of samples of commercially grown Cox's Orange Pippin from various parts of the country were stored at the Research Station in air at 37° F. and in gas (3 per cent oxygen and 5 per cent carbon dioxide) at 38-39° F., and examined on 13th January and 17th February respectively. The apples from gas storage were less mature than those from cold storage and many samples also had less wastage due to *Gloeosporium* rots. An examination of some of these samples provided evidence that gas storage had a greater influence in reducing rots when *G. album* was the predominating species (see p. 140). There were clear indications of the value of captan in controlling *Gloeosporium* rots both when applied as special sprays in the late summer and also when used in the routine spring and summer sprays against scab. Light soils, arable culture and high nitrogen tended to be associated with high wastage through rotting. Bitter pit was a serious trouble in some samples, mainly those from light soils, especially where there was a light crop on young trees and the fruits were accordingly large.

The 32 orchards, selected in 1957 on their cropping and the storage of their fruit, were again visited in July, and leaf samples for chemical analyses (cf. p. 86) were collected from the marked trees.

The Cox's Orange Pippin trees, raised in 1957 on M.IX rootstocks with selected scionwood to investigate the permanence of certain fruit characters including storage quality, were planted out during the winter and later deblossomed. They have made good growth and should yield some fruit during the coming season. Arrangements are in progress to plant out a similar set of trees on virus-tested M.VII rootstock on two commercial holdings.

Fruit development in Cox's Orange Pippin

The histological investigations were continued, paying particular attention to the rate and duration of cell division and cell expansion in the cortex. In the 1957 season, there was a slow increase

in cell number and cell weight for the first fortnight after pollination. During the next fortnight cell number increased rapidly and exponentially, then the rate of division declined, and ceased about 50 to 60 days after pollination. Cell weight increased exponentially during the whole period of rapid and declining rate of cell division.

Publication During the Year

T64 Montgomery, H. B. S. (1958). **The effect of storage conditions on the incidence of *Gloeosporium* rots of apple fruits.** *Nature, Lond.*, **182**, 737-8.

XI. MISCELLANEOUS PUBLICATIONS

T63 Montgomery, H. B. S. (1958). **Progress in research in fruit crops in 1957.** *Rep. E. Malling Res. Sta. for 1957*, 164-9.

T65 ——— (1958). **East Malling Mother Trees.** *Grower*, **50**, 285; *Comm. Grower*, No. 3206, 255-7; *Gdnrs' Chron.*, **144**, 100 and 106.

L31 Hoblyn, T. N. (1958). **Practical aspects of field experimentation with fruit.** *Rep. E. Malling Res. Sta. for 1957*, 43-7.

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

METEOROLOGICAL FACTORS IN THE GROWTH OF PLANTS

By SIR DAVID BRUNT, M.A., Sc.D., D.Sc., F.R.S.

The control of atmospheric temperature by the ground

It is perhaps unnecessary for me to emphasize the well-known fact that the immediate control of the temperature of the surface layers of air is effected by the temperature of the ground. On a sunny day, there is a measurable but small heating of the air by direct absorption of incoming solar radiation, but most of the incoming solar radiation is absorbed by the surface of the ground, and the ground, thus warmed, heats in turn the air above it.

Most surfaces of ground, whether soil, plants, water or ice, radiate heat upwards, at a rate which is proportional to the fourth power of the absolute temperature, and is in practice almost independent of the nature of the surface, which radiates nearly like a perfect black body. The rate of radiation of heat from the ground, whose absolute temperature is T is expressed mathematically as σT^4 gramme calories per cm^2 per second where σ is known as Stefan's constant. We shall denote the quantity σT^4 by the letter B.

The water vapour and carbon dioxide in the atmosphere send out long-wave radiation, and the downward component of this radiation is absorbed at the ground, and so in part compensates for the loss of heat by the ground by its own radiation upwards.

If the downward radiation from the atmosphere to the ground on a cloudless night is represented by R, the net loss of heat from the ground is B—R. It has been shown that

$$\frac{R}{B} = 0{\cdot}52 + 0{\cdot}065\sqrt{e} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where e is the vapour pressure in millibars (Brunt, 1932). In the same paper it was shown that if T_1 is the surface temperature at sunset, and T its value at t hours after sunset, then

$$T_1 - T = \frac{2}{\sqrt{\pi}} \frac{B-R}{\sqrt{ks}} \sqrt{t} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where k is the thermal conductivity of the ground, and s its heat capacity. This indicates that the trace of a thermograph on a clear night should be of the form of a parabola from sunset onwards, the temperature falling rapidly after sunset, and its rate of fall diminishing less rapidly later.

Equation(2) above can be used to compute the night fall of temperature from sunset to sunrise ; it also yields an explanation of the effect of the varying content of soils. Since the rate of fall of temperature in given meteorological conditions is inversely proportional to $\sqrt{ks}$, it indicates that this rate is greatest over those soils that have low values of k and s. Now the thermal conductivity and the heat capacity of a soil are the resultants of the same quantities for soil particles and for the air in the soil, and since the thermal conductivity and heat capacity of air are both very low, it follows that k and s will both be lowest for those soils which contain most air.

It is the sandy soil which contains most air, and so the lowest night minimum temperature should occur over sand. It is easy to check up on the accuracy of this conclusion. South Farnborough and Croydon both have meteorological stations, which have usually the same general weather conditions. South Farnborough is on greensand, and Croydon on a sticky clay, and on clear nights the minimum temperature at the former is some 5° F. lower than at the latter.

The argument by which we established our main result could be inverted to show that on a

* The eleventh Amos Memorial Lecture, delivered at East Malling Research Station on 13th November 1958.

sunny day the maximum temperature of the afternoon will be higher over the soil containing the more air. The maximum afternoon temperature on a sunny day is higher by 4-5° F. at South Farnborough than at Croydon.

The sixth Chapter of the Book of Judges affords a most interesting application of a knowledge of soils, in the description of the miracles of Gideon's Fleece, and I will quote the appropriate verses, starting at verse 36 :

36. And Gideon said unto God, if thou wilt save Israel by mine hand, as thou has said.
37. Behold, I will put a fleece of wool in the floor, and if the dew be on the fleece only, and it be dry on all the earth beside then shall I know that thou wilt save Israel by mine hand, as thou hast said.
38. And it was so, for he rose early on the morrow, and thrust the fleece together, and wringed the dew out of the fleece, a bowl full of water.

But Gideon was not satisfied with this one successful experiment and carried out a second, as follows :

39. And Gideon said unto God, Let not thine anger be hot against me, and I will speak but this once ; let me prove, I pray thee but this once with the fleece : let it now be dry only upon the fleece, and upon all the ground let there be dew.
40. And God did so that night, for it was dry upon the fleece only, and there was dew on all the ground.

Now a fleece is over 90 per cent air, and so has extremely low thermal conductivity and heat capacity. Its rate of fall of temperature will far exceed that of any kind of soil, and its temperature may fall below the dew-point of the atmosphere, while the temperature of the ambient ground is still above the dew-point. This is sufficient to explain Gideon's first experiment.

There are circumstances in which water vapour diffuses upward into the atmosphere through the surface of the ground. This can occur when the ground below the surface is still moist from previous rain, while its surface may be dry. The water vapour diffused into the atmosphere, meeting the cooled grass or the undersides of cold stones, will then be condensed into liquid water. Thus dew will form upon the ground round about, but the fleece, with the skin underneath, will be impervious to the rising vapour. The retention of stones in the soil is therefore beneficial in retaining water in the soil.

I do not find it difficult to believe that a man of Gideon's outstanding ability, who must have slept on a fleece in the open air times without number, should have observed these phenomena.

When the air in the soil is replaced by water, then since the thermal conductivity and heat capacity of water are much greater than the corresponding values for air, both k and s are thereby increased, so that the rate of fall of temperature of the surface of the ground is considerably decreased. For a light soil containing 20 per cent of water $\sqrt{ks}$ is five times as great as that for the same soil when dry. With the addition of water the value of $\sqrt{ks}$ of the soil increases steadily at first, but as the soil becomes waterlogged it again falls to a value little greater than for dry soil, maximum conductivity being associated with water content of 30 per cent.

For a sandy loam the value of $1/\sqrt{ks}$ varies as follows :

	value of $1/\sqrt{ks}$
when dry	57
with 10 per cent water	40
with 20 per cent	12
for snow	250

From equation(2) it follows that the fall of temperature from sunset to sunrise is proportional to the square root of the time from sunset to sunrise. If we regard the value of $\sqrt{ks}$ for dry soil as appropriate to summer conditions, and those for soil containing 20 per cent water (by weight) as appropriate to winter, then the ratio of the fall of temperature from sunset to sunrise for summer and winter is $\frac{57}{12} \times \sqrt{\text{ratio of lengths of time from sunset to sunrise}}$

For June and December this ratio comes out as $\frac{57}{12} \times \sqrt{7 \cdot 4/16} = 3 \cdot 2$

This is in close agreement with the observed ratio in southern England.

A covering of freshly fallen snow reflects most of the incident radiation, and so the temperature of the air above the snow will show little variation by day. At night the snow surface will cool rapidly by radiation, on account of the low heat capacity, and low conductivity of the snow.

Franklin (1919) quotes data showing air temperature over a layer of snow three inches deep varying from −15° C. to −4·6° C., a range of nearly 19° F., while the surface temperature of the ground underneath the snow remained steady at 0° C.

Sand, especially sand in freshly formed dunes, has a very high content of air, and a low content of water. Older dunes are usually grey coloured, due to the higher content of humus, and have lower reflecting power, and a higher absorbing power, than the yellow sand of the freshly formed dunes, and accordingly have higher temperatures in the air immediately above them. The older dunes therefore produce conditions more suitable for growth than those over the younger dunes.

The effect of lack of soil drainage

Over a heavy soil such as clay water tends to lie in pools, only slowly percolating into the ground, while the constant evaporation of the water will produce a superimposed lowering of the air temperature and an increase of humidity both by day and by night. Once the surface water has disappeared by percolation and evaporation, and the surface soil has become dry, the temperature of the air above the soil will be lower by day, and higher by night, than those above a similar soil not watered.

By watering a dry soil sufficiently early to permit the surface to become dry before sunset, it is possible to ensure that the fall of temperature of the air above it shall be appreciably less than over unwatered soil. This experiment is, unfortunately, only practicable on a small scale, but it does in fact make it possible to protect ones's smaller plants. Large scale spraying of soil is not an economic method of frost protection.

Conditions that favour the occurrence of frost

The conditions which favour the occurrence of severe frost are :

(a) cloudless skies
(b) absence of wind
(c) low vapour pressure in the atmosphere
(d) low thermal conductivity and heat content of the ground.

When the sky is covered with cloud, the net radiation loss from the ground will depend on the height of the cloud, being about 80 per cent of the clear sky value with cirro-stratus cloud, about 23 per cent of the clear sky value with alto-cumulus cloud, and about 14 per cent with stratus or strato-cumulus cloud. Clearly, only with cirro-stratus cloud is there any risk of frost occurring.

A complete covering of quite low cloud gives so small a net loss of heat from the ground by radiation that it can be neglected.

The forecasting of intensity of radiation frost

Since radiation frost of any marked severity can only occur on clear nights, the forecasting of such frosts requires in the first place that the occurrence of a clear sky at night can be foreseen with confidence. Granted that the occurrence of low temperatures can be foreseen, the magnitude of the night fall of temperature can be computed by the use of the formula given earlier, but it is not always possible to foretell accurately the variation of cloud amount in the evening and night, although it is a recognized fact that uniform sheets of relatively low cloud tend to clear rapidly after sunset. Thus, when frost is actually foretold, the prediction may be falsified by the subsequent drift of cloud over the area under consideration. A forecaster dealing with an area with which he is familiar will, however, seldom go far wrong in his forecast of night clouds.

There are also occasions when a sheet of low cloud is anticipated to last all night, and the cloud, instead of persisting, rapidly clears. If the clearing happens in the early part of the night, the subsequent fall of surface temperature will be roughly equal to the fall occurring with a sky clear all night.

As was pointed out earlier, night frost can occur with a sky covered by high cirro-stratus cloud, the night fall of temperature with such cloud being about 80 per cent of the clear sky value.

There is thus no simple golden rule for forecasting the intensity of night frost, even on flat ground. In a hollow inundated with cold air brought there by a katabatic wind, the estimation of the lowest temperature reached within the hollow is tricky and subject to some uncertainty. Experience has shown that in some hollows night frosts can occur in almost any month of the year, and are, therefore, liable to occur rather unexpectedly.

The effect of aspect of sloping ground on soil temperature

In the British Isles, the sun, even at maximum elevation in the early growing season, is low in the sky, and the effect of aspect on soil temperature may be very noticeable. A sloping field facing south may have soil temperatures at 1½ in. below the surface 15° F. higher, with corresponding lower moisture content, than a nearby field facing north. Aspect may also affect exposure to the wind, a

gusty wind having marked effects on the internal temperature of the leaves. Fritzsche (1933) recorded differences of temperature up to 12·9° F. between air and leaves in a gusty wind.

The effect of soil covering

The surface of bare soil is cooler on a clear day and warmer on a clear night than that of similar soil which is grass covered, the effect of a grass covering increasing as the length of the grass increases. The reason is readily found. Long grass retains the same air between its stalks more effectively than short grass, while over bare soil there are always intermittent motions of air which prevent the same air from remaining in contact with the cold ground.

In addition, the grass roots may form a matted layer having very low vertical conductivity, capable of enhancing the fall of temperature on a clear night. I remember seeing some observations of extremely low air temperature at a place in the Romney Marshes, where the coarse grass has a matted layer of roots, which, at least in places, was a foot in thickness.

Cornford (1938) has given a table of minimum air temperatures over various types of soil covering, on flat land at East Peckham, Kent, on the morning of 30th May, 1937—

	°F.
Bare soil	49·5
In a wood	49·0
Among raspberry canes	48·2
Meadow	45·7
Meadow, longer grass	43·0
Grass and clover	43·5

These figures indicate that in the early morning the air above grass is colder than the air above bare ground or in a wood, and that the air above long grass is then colder that the air above short grass. It is thus advisable to keep any grass growing in an orchard as short as is practicable, and also to keep short any grass growing on a slope from which katabatic winds can flow downward into an orchard or garden.

To understand the distribution of temperature above or within any growing plant it is necessary to take into account the fact that the daytime absorption of solar radiation and the night-time radiation upwards of infra-red radiation, is effected by the part of the foliage which is visible from above, and the magnitude of this effect depends on the closeness of the foliage. Thus, in the table quoted from Cornford, the minimum temperature among raspberry canes is lower than that in a wood, the reason being that raspberry canes are planted at some distance apart, permitting solar radiation to penetrate rather freely to the ground, and the infra-red radiation from the ground at night to pass outwards into the air. In a wood with a complete canopy of leaves little or no radiation passes from the ground to levels above the canopy of leaves. The outward radiation proceeds upward from the canopy of leaves, which are cooled in consequence. The air at the level of the canopy is cooled, and tends to fall to the ground, and in the process of descending becomes mixed with the air below the canopy, so that the fall of temperature at the level of 3 ft above the ground is little greater than over bare soil. In a wood in which there are gaps in the canopy there will occur lower night minimum temperatures and higher day maximum temperatures than under a complete canopy.

Geiger has given observations within tall grass, showing that the absorption of incoming solar radiation is very great at the uppermost level at which the grasses are densely packed together. He has also given measurements of temperature at different heights within growing corn, showing that while the crop is short and the separate plants well spaced out, extremes of day and night temperatures will differ little from those above bare ground. The highest temperature will be observed at the ground, during the stage of growth until the development of the leaves on the plant is sufficient to stop both downward radiation from the sun, and outward infra-red radiation from the ground. Once this stage is reached, the maximum day temperature is found at some distance above the ground, and when the corn is ripening the maximum temperature (near the ground) is so high that the air within the crop is unstable. In these circumstances convection currents can occur, having sufficient magnitude to carry upwards a sailplane.

In a bed of flowers such as antirrhinum whose upper horizontal leaves absorb incoming solar radiation, and send out infra-red radiation at night, the minimum night temperature within the crop is just at the ground, in all stages of growth.

Temperature is not the only factor whose value is affected by plants. When within grass, or other crops there are present such plants as clover, which produces leaves lying close to the ground, they produce a climate under these leaves which may be cool and humid, even when the tops of the grass or other main crop are in very dry warm air. Such conditions are favourable to the proliferation of many plant pests.

Within an oakwood the vegetable litter covering the ground in winter can afford very marked protection to the roots of plants. F. Firbas (1927) recorded observations showing that at a depth of 2 cm. beneath soil covered with litter the temperature of the soil can be as much as 26° C. (47° F.) higher than that of the air at a height of 1 m. above the ground. The litter is usually dark and readily absorbs incident radiation, while its components are usually laid horizontally, and have little power of vertical conduction. Thus only the upper surface of the litter is effectively cooled by radiation.

While we have seen that both the nature of the soil and of the soil covering have marked effects on the temperature of the air, there is another feature of the phenomena which needs to be emphasized, namely, the temperature within the soil. The soil which has the lowest conductivity will be most subject to surface frost, but will usually freeze to the least depth, and bare soil will freeze to a greater depth than grass covered soil. Salisbury (1939) gave some data for the freezing of a sandy loam by a sudden frost. The soil, where bare, was frozen to a depth of 5·5 to 8·8 cm. Under rough grass this was reduced to 2·5 to 3·5 cm. while under bushes the depth of frozen soil was less than 2 cm. In a hazel copse on the same soil the ground was frozen to a depth of not more than 1·5 cm., even where the litter on the ground was sparse, and where the litter was appreciable no frozen soil could be found.

Katabatic winds and minimum temperatures

When on a clear quiet night, the ground is cooled by radiation to the sky, the air in immediate contact with the ground is rapidly cooled. Over the surface of sloping ground the cold air flows downhill, much as water does, following any course hollowed in the slope, filling the lower ground with a pool of cold air. If the low ground is in the form of a hollow, from which the cold air cannot flow away, much lower air temperature will occur there than over flat ground in the same region. The so-called sheltered valley is subjected to frequent and severe frost, and is not a suitable location for either a home or an orchard.

Katabatic, or downhill winds, require for their full development a clear sky and a very light wind. When the daytime wind continues to blow briskly at night, the surface cooling is lessened and katabatic winds do not develop, or fail to attain the same strength as on windless nights. When the night winds are brisk, the night minimum temperature is lower on high than on low ground, the maximum difference of temperature being 5·4° F. per 1,000 ft. difference of elevation of the high and low ground. Among high hills the katabatic wind is developed only over the lower slopes, the normal daytime wind persisting over the higher ground, with a zone of calm at the intermediate level.

The development of a strong katabatic wind requires rapid cooling of the ground, and these winds will be strongest where the nature of the soil or soil covering favours rapid cooling.

Katabatic winds are strongest over snow covered slopes, while a covering of long grass would be the next most favourable covering for their development. Any attempt to counter the low temperature in a katabatic wind by the use of orchard heaters is doomed to failure, as the loss of heat from plants in the downhill flowing air would be much more rapid than the input of heat by the orchard heaters. Moreover, the air immediately warmed by the heaters is carried away by the downhill wind.

It is possible in some locations to deviate the katabatic wind so that it does not affect, say, an orchard or garden, by erecting a wall, a thick hedge, or hessian screen, diagonally across the upper slopes.

It is worth recording that on sloping ground the katabatic wind usually starts well up the slope, and may, in fact, be detectable as a layer of cold air initially of a thickness of an inch or two. As it flows downhill the layer of downward moving cold air becomes deeper. It thus appears probable that on slopes subject to katabatic winds, fruit trees might be profitably planted on the upper slopes, where even the lower branches would be above the cold air. Small bushes, if they are to be planted at all in such locations, should be planted high up on the slope where the downward moving air is only a shallow current. I have seen gardens on sloping ground in which shrubs were planted at the bottom of the slope.

It is perhaps fortunate that the season in which katabatic winds are most frequent is the summer, when they can do relatively little harm to plants. It is my impression that far more could be done to deviate katabatic winds into a course in which the damage produced to crops, or to the comfort of human beings, would be minimized.

References

(1) Brunt, D. (1932). Notes on radiation in the atmosphere. I. *Quart. J. R. met. Soc.*, **58**, 389-420.
(2) Cornford, C. E. (1938). Katabatic winds and the prevention of frost damage. *Quart. J. R. met. Soc.*, **64**, 553-87.

(3) FIRBAS, F. (1927). *Beih. bot. Zbl.*, **44**, 179-98.
(4) FRANKLIN, T. B. (1919). The effects of weather changes on soil temperatures. *Proc. Roy. Soc. Edinb.*, **40**, 56-79.
(5) FRITZSCHE, G. (1933). *Beih. bot. Zbl.*, **50**, 251-322.
(6) SALISBURY, E. J. (1939). Ecological aspects of meteorology. (The G. J. Symons Memorial Lecture, 1939). *Quart. J. R. met. Soc.*, **65**, 337-58.

POMOLOGY

APPLE ROOTSTOCK STUDIES: GROWTH AND CROPPING OF COX'S ORANGE PIPPIN ON SOME MALLING AND MALLING-MERTON ROOTSTOCKS

By A. P. PRESTON

A new set of apple rootstocks, bred jointly by M. B. Crane at the John Innes Horticultural Institution when at Merton and by H. M. Tydeman at East Malling (1, 3) and known as the Malling-Merton rootstocks, was distributed after initial testing at East Malling to research institutes abroad in 1952. For fruit growers in England, five of these new rootstocks were selected as being likely improvements upon, or additions to, existing clones; these were named Malling-Merton 104, MM.106, MM.109, MM.111 and Malling XXV. The first four rootstocks are highly resistant to the woolly aphid (*Eriosoma lanigerum* Hausm.). This resistance is confined to the rootstock and it does not render scions worked upon it resistant also. The fifth, M.XXV, is not so highly resistant and was therefore added to the original Malling rootstocks. Trees on these five rootstocks are now available from nurserymen.

Botanical descriptions of the rootstocks (11) and reports of their early performance in field trials on two different soils at East Malling (4, 6) have already been published. This paper presents the latest information on the growth and cropping of 13-year-old trees of Cox's Orange Pippin on the five new rootstocks, together with that for comparable trees on some of the original Malling clones in these trials.

Material

One-year-old trees were planted during the winter of 1945-6 in four separate trials. Trials A and B were planted on a sandy loam soil of the Malling Series and trials C and D on a gravelly phase of the Bearsted Series of sandy texture. Each trial included trees of Cox's Orange Pippin, Jonathan and Ellison's Orange and contained four trees of each variety on each rootstock (4). Tree spacing was 15 × 18 ft in Trial A, 18 × 20 ft in Trial B, 15 ft square in Trial C and 18 ft square in Trial D. For brevity this report deals only with Cox's Orange Pippin, but the figures for Jonathan and Ellison's Orange support those for Cox with a few exceptions.

All trees have been pruned by the regulated method (5), leader tipping being discontinued after the third winter. Trials A and B have been clean cultivated with autumn weeds allowed to grow. Trials C and D were also clean cultivated until the spring of 1956 when they were grassed down. The manurial treatment for each soil has differed according to its requirements, but the two trials within each soil type have been uniformly manured.

Results

Tree size

Trunk girth has been measured annually and periodic measurements of tree height and branch spread have been made. In all cases trees on the loam soil were larger than those on the sand. Analyses of variance were carried out on the logarithms of the girths in 1957; in Table I these are transformed back to the mean trunk girths, so that the significant differences become ratios.

In Trials A and C, on loam and sand soils respectively, trees on MM.106 did not differ significantly in girth from those on M.VII, neither did trees on MM.104 differ from those on M.IV. Trees on the dwarfing M.IX were definitely smaller than those on MM.106 on both soils. In Trials B and D the relative order of rootstocks differed on the two soils. On the loam (Trial B) trees on MM.111 and M.II were similar in size, whereas on the sand (Trial D) trees on MM.111 were the larger. Trees on MM.109 and the new M.XXV were similar to those on the very vigorous M.XVI on loam (Trial B) but trees on M.XXV were significantly smaller than those on M.XVI on the sand (Trial D).

Data for tree height and area of branch spread (mean diameter squared) show close agreement, in the relative order of rootstocks, with those for trunk girth (Table II). Analyses of variance for these data were not made because during the last three years variation between trees on the more

TABLE I

MEAN TRUNK GIRTH (CM.) AT 12 YEARS OLD (1957)

							Percentage increase for significance (P = 0·05)
TRIAL A	M.IX	MM.106	M.VII	M.IV	MM.104		
On loam	17·0	30·5	31·0	39·7	42·5		17
TRIAL C							
On sand	12·2	19·6	22·4	27·9	29·2		29
TRIAL B	MM.111	M.II	M.XXV	M.XVI	MM.109	M.IV	
On loam	35·2	35·6	38·5	38·8	41·0	43·5	12
TRIAL D	M.II	M.XXV	M.IV	MM.111	MM.109	M.XVI	
On sand	22·6	25·0	26·2	26·9	29·9	31·3	17

vigorous rootstocks had fallen, indicating that overcrowding was beginning to affect the measurements, especially in Trial B and with trees on M.IV and MM.104 in Trial A.

TABLE II

MEAN HEIGHT (H) IN METRES AND AREA OF BRANCH SPREAD (S) IN SQUARE METRES AT 12 YEARS OLD (1957)

TRIAL A	M.IX	M.VII	MM.106	M.IV	MM.104	
H	1·8	2·6	2·7	3·4	3·7	
S	9·6	16·0	16·8	25·0	26·0	
TRIAL C	M.IX	MM.106	M.VII	M.IV	MM.104	
H	1·6	2·2	2·5	2·8	3·1	
S	3·2	7·8	11·6	13·7	16·8	
TRIAL B	M.II	MM.111	M.XXV	MM.109	M.XVI	M.IV
H	3·4	3·3	3·5	3·7	3·8	3·8
S	20·2	23·0	26·0	26·0	26·0	29·2
TRIAL D	M.II	M.IV	M.XXV	MM.111	MM.109	M.XVI
H	2·7	3·0	2·9	3·0	3·4	3·3
S	10·2	13·7	15·2	16·8	17·6	18·5

In Trial A on the loam, trees on MM.106 and M.VII were almost identical in tree height and area of branch spread whereas in Trial C on the sand, trees on MM.106 were smaller than those on M.VII though they were considerably larger than trees on M.IX. The early vigour of trees on the moderately vigorous M.IV (2) was again demonstrated, especially in the trials on loam where they were as large as trees on the very vigorous M.XVI even at 12 years of age. This point will be discussed later.

Anchorage

In the earlier papers on these trials attention was given to the anchorage of trees on the different rootstocks. Most of the new rootstocks, including all five now under review, were shown to be better anchored than M.IV and some, for example MM.104, were as well anchored as the very vigorous M.XVI. These early records have since been substantiated, especially during a severe summer gale in 1956, one year after the trees had been unstaked (7). MM.104 has given the best anchored trees in the trials, followed by trees on M.XVI, M.XXV and M.II in descending order. Trees on MM.109 have proved less well anchored than those on M.XVI, especially on the sandy soil.

Cropping

Most trees carried their first crop in 1948, the third summer after planting. The total crop per tree for the 11-year period up to and including 1958, together with the differences required for significance at the 5 per cent level, are shown in Table III. The crops from trees on MM.104 and M.IV in

Trial C in 1954 were estimated* to be 23·5 and 18·6 lb. respectively. These estimates are included in Table III, and since the total crops from trees on M.IV in trials C and D are similar, would appear to be valid. In any case, it is clear that the yield on MM.104 is significantly greater than that on M.IV in Trial A, and nearly so in Trial C.

TABLE III

TOTAL CROP PER TREE (LB.), 1948-58

							Sig. diff. (P = 0·05)
TRIAL A	M.IX 212·8	MM.106 446·2	M.VII 491·9	M.IV 662·0	MM.104 868·2		136·45
TRIAL C	110·5	265·3	283·3	333·0	427·2		100·55
TRIAL B	M.XVI 460·7	M.II 572·8	MM.109 661·1	M.XXV 743·6	M.IV 757·5	MM.111 758·3	215·94
TRIAL D	M.IV 303·9	M.II 311·8	MM.109 390·3	M.XXV 405·6	M.XVI 410·2	MM.111 472·9	131·06

In spite of high tree to tree variation on the sand soil the performance of trees on MM.111 and M.XVI in Trial D have been outstandingly good. Trees on M.XXV, although smaller than those on M.XVI, cropped almost as heavily.

Under the better growing conditions of the loam soil, yields on all rootstocks were high when judged by past fruit growing standards. The annual yields from trees on MM.106 and M.VII were almost identical, the differences averaging only 4 lb. per tree. M.IV which, among the original Malling rootstock clones, induces some of the heaviest bearing trees (2, 8) may be taken as a measure of high yield in these trials also. There was a highly significant difference ($P = 0·01$) between the yields from trees on M.IV and those on MM.104 in favour of trees on the latter rootstock. In Trial B trees on MM.111 were as heavy bearing as those on M.IV and heavier bearing than those on M.II ($P < 0·1$). In the very vigorous group the yields from trees on MM.109 were higher than those on M.XVI but the difference was not significant at the 5 per cent level. Trees on the new M.XXV were considerably heavier bearing than those on M.XVI.

Fruit size and colour

The fruit was not thinned. Fruit size, measured by the weight of 100 fruits, was greater on the loam soil than on the sand (Table IV). Differences between rootstocks were small. In both trials on the sandy soil trees on M.IV yielded some of the largest fruits, and in Trials B and D trees on the new rootstocks yielded larger fruit than did those on either M.II or M.XVI. The latter trees, however, together with those on MM.104, averaged five fruits to the pound, or an equivalent size grade of $2\frac{1}{2}$ to $2\frac{3}{4}$ in. diameter, a satisfactory size for Cox's.

TABLE IV

FRUIT SIZE ; MEAN WEIGHT OF 100 FRUITS (LB.), 1952-7

TRIAL A	MM.104 21·8	MM.106 22·4	M.VII 23·4	M.IV 24·1	M.IX 24·3	
TRIAL C	MM.104 20·5	MM.106 20·7	M.VII 21·0	M.IX 21·2	M.IV 27·5	
TRIAL B	M.XVI 22·6	M.II 22·9	M.IV 24·4	M.XXV 24·5	MM.109 24·7	MM.111 26·7
TRIAL D	M.II 21·1	M.XVI 21·6	MM.111 22·0	M.XXV 22·6	M.IV 23·3	MM.109 23·4

* The original records were lost.

The amount of red colour and the intensity of yellow colour were each recorded in five categories on the picked fruit in trays ; category five was the highest in each case. The mean grades (Table V) show the higher red colour and earlier ripening (as measured by the intensity of yellow colour) characteristic of fruits from trees on the dwarfing M.IX (9). The differences in fruit colour between trees on different rootstocks are relatively small, due no doubt to the lightness of pruning. This resulted in more spreading branches than with harder pruned trees, giving the fruits better exposure to sun and moisture, especially with trees on vigorous and very vigorous rootstocks such as MM.104 and MM.111, M.XVI and M.XXV.

TABLE V

FRUIT COLOUR ; MEAN GRADES FOR AMOUNT OF RED COLOUR AND INTENSITY OF YELLOW COLOUR (MAXIMUM 5·0)

TRIAL A	M.VII	MM.106	M.IV	MM.104	M.IX	
Red	2·8	2·9	2·9	3·0	3·0	
Yellow	3·2	3·3	3·6	3·0	3·7	
TRIAL C	M.VII	MM.106	MM.104	M.IV	M.IX	
Red	2·3	2·3	2·3	2·4	2·4	
Yellow	2·8	2·8	2·8	3·0	3·0	
TRIAL B	MM.109	M.II	M.IV	M.XVI	M.XXV	MM.111
Red	2·4	2·7	2·7	2·7	2·7	2·9
Yellow	3·4	3·0	3·3	3·3	3·3	3·2
TRIAL D	M.XVI	M.XXV	MM.109	MM.111	M.II	M.IV
Red	2·2	2·4	2·5	2·6	2·7	2·9
Yellow	2·7	2·8	2·8	3·3	3·2	3·7

Crop in relation to tree spacing

Cumulative yields per acre up to 8 and 13 years old have been estimated for trees on the loam soil at appropriate planting distances (Table VI). The actual cropping figures per tree at the experimental distances listed on page 47 have been used in this estimate.

TABLE VI

ESTIMATED CUMULATIVE YIELDS PER ACRE IN BUSHELS (40 LB.) AT APPROPRIATE SPACING FOR TREES ON LOAM SOIL

Rootstock	Distance apart in feet	Number of trees per acre	Cumulative yield	
			at 8 years*	at 13 years*
M.IX	12	302	543	1,313
M.VII	15	193	699	1,987
MM.106	15	193	699	1,785
M.IV	17	150	645	2,066
M.II	17	150	416	1,646
MM.111	17	150	585	2,242
MM.104	17	150	675	2,666
MM.109	24	75	210	984
M.XXV	24	75	262	1,125
M.XVI	24	75	180	660

* age from budding

Trees on MM.106 require a spacing similar to that of trees on M.VII, except on light sandy soils where they could be planted closer. In the early years the yields from these two sets of trees were identical—but by the thirteenth year trees on M.VII had yielded slightly more fruit (10 per cent).

In the vigorous group, trees on the new MM.104 and MM.111 were superior to those on M.II both at 8 and 13 years old, as were trees on MM.109 and M.XXV to those on M.XVI in the very vigorous

group. On the basis of these data it is clear that if trees on the vigorous MM.104 were planted at 17 ft square, with provision for tree-thinning, their estimated yields per acre would have been 24 per cent greater than those from trees on the productive M.IX (planted at 12 ft square) at eight years of age, and double their yield at thirteen years. Even if half the trees on MM.104 were removed at perhaps the eleventh year, the last three years' estimated yield from the remaining trees (at 75 trees per acre) would be 31 per cent higher than that from trees on M.IX (at 302 trees per acre) during the same period. With trees on both MM.104 and MM.111 a flexible planting plan, similar to that for trees on M.II, seems desirable, especially on good loam soils ; for example, an initial spacing of 17 ft square which could be thinned to 24 ft if necessary.

In the very vigorous group, trees on MM.109 and M.XXV need a spacing similar to that for trees on M.XVI on good soils, though trees on M.XXV may not need so much room on sandy soil.

Discussion

This assessment of the comparative value of the five new rootstocks is based upon results at one centre. Younger trials are now under way in other parts of England together with some 28 sets of demonstration trees, planted in most of the fruit growing areas. Trials have also been planted in other countries. Thus in the near future there will be additional evidence to support, or modify, results already reported from East Malling. In some areas where winter injury is a major trouble these new rootstocks need testing for resistance to such damage. For areas where collar rot (*Phytophthora cactorum* (L. and C.) Schroet) is troublesome, attention is drawn to recent tests which have shown rootstocks MM.104, MM.106, MM.109, MM.111 and M.XXV together with M.II, M.VII and M.IX to be highly resistant to several isolates of the fungus (10).

Unlike trees on M.VII, those on MM.106 have not produced suckers. Apart from this characteristic there seems little to recommend MM.106 as a replacement for M.VII, at least on good loam soils. On the sandy soil, however, trees on MM.106 have filled a unique position in so far as they are larger than trees on M.IX yet considerably less spreading than those on M.VII whose cropping they have nearly equalled (Tables II and III). On similar poor sandy soils it might pay to use trees on MM.106 rather than those on M.IX.

On the loam soil trees on MM.111 were similar in size to those on the popular M.II, but they cropped more heavily and were in fact as heavy bearing as the larger trees on M.IV which are themselves outstanding yielders. Furthermore, trees on MM.111 on the sandy soil recovered from the serious summer droughts of 1947 and 1949 better than did trees on M.II, many of which are still small and stunted (Tables I and II).

It is perhaps too early to make a final assessment of the relative value of trees on MM.109, M.XXV and M.XVI in the very vigorous group. Trees on MM.109, though heavier cropping than those on M.XVI, are not so well anchored. Trees on M.XXV were outstanding for early bearing within this vigour group, yielding almost as much as those on MM.111 during the first seven years, a level of cropping which they have since maintained.

From data in this paper it is clear that MM.104 is the most outstanding of the five new rootstocks. It produces well anchored, heavy cropping trees somewhat larger than those on M.II. By adopting a light pruning method full use has been made of the initial vigour of this rootstock which has resulted in heavy bearing early in the life of the tree yet maintaining a tree of satisfactory orchard size and shape. In this respect this rootstock has many of the desirable qualities of M.IV, for example, in building a large tree quickly, but without the serious disadvantage of poor anchorage common with trees on M.IV. It should be borne in mind however, that harder, or more persistent, leader tipping may result in a larger tree than in these trials.

Trees on MM.104, M.IV and M.XVI were similar in size (Tables I and II). From past experience trees on M.XVI should be considerably larger than trees on M.IV by the fifteenth year (8), although in the earlier years trees on these two rootstocks are almost identical in size though *not* in cropping. In the present trials it is possible that the light method of pruning, which has resulted in trees on M.XVI coming into bearing much earlier than they did in the original Malling rootstock trials, accounts for their not yet having become larger than trees on M.IV.

The new rootstock clones MM.104, MM.111 and M.XXV have at East Malling shown distinct improvements upon existing clones in the first 13 years ; MM.106 and MM.109 appear to be more suited for use under special circumstances.

Summary

The growth and cropping of 13-year-old trees of Cox's Orange Pippin on five new apple rootstock clones are reported. They were Malling-Merton 104, MM.106, MM.109, MM.111 and M.XXV. These were compared with trees on M.IX, M.VII, M.IV, M.II and M.XVI in trials on a loam soil (Malling

Series) and duplicated on a sandy soil (Bearsted Series). All trees were lightly pruned by the regulated method.

Trees on MM.106 were almost identical in size and cropping with those on M.VII on the loam soil. On the sandy soil trees on MM.106 were smaller than those on M.VII though considerably larger than on M.IX.

MM.111 made trees equal in size to those on M.II but were heavier cropping. On loam, trees on MM.109 and M.XXV were similar in size to those on M.XVI but were heavier cropping. Trees on M.XXV were outstanding, within their vigour group, for early cropping.

Trees on MM.104 were somewhat larger than those on M.II, and yielded more heavily ; they were as heavy bearing as those on the precocious M.IV during the early years, and by the fourteenth year had surpassed them. This rootstock has given an outstandingly good performance, making well anchored trees free from suckering and which have responded well to the light, labour-saving, method of pruning used in these trials.

References

(1) Crane, M. B., Greenslade, R. M., Massee, A. M., and Tydeman, H. M. (1936). Studies on the resistance and immunity of apples to the woolly aphis *Eriosoma lanigerum* (Hausm.). *J. Pomol.*, **14**, 137-63.

(2) Hatton, R. G. (1935). Apple rootstock studies. Effect of layered stocks upon the vigour and cropping of certain scions. *J. Pomol.*, **13**, 293-350.

(3) —— ——, *et. al.* (1937). The problems raised by the woolly aphis of the apple. A case for team research. *Ann. appl. Biol.*, **24**, 169-210.

(4) Preston, A. P. (1953). Some new apple rootstocks. *Proc. 13th int. hort. Congr., London, 1952*, **1**, 267-81.

(5) ——— (1954). Pruning young apple trees by the regulated method. *Rep. E. Malling Res. Sta. for 1953*, 200-1.

(6) ——— (1955). Apple rootstock studies : Malling-Merton rootstocks. *J. hort. Sci.*, **30**, 25-33.

(7) ——— (1957). Summer gale damage to apple rootstock and pruning trials in 1956. *Rep. E. Malling Res. Sta. for 1956*, 85-8.

(8) ——— (1959). Apple rootstock studies: Thirty-five years' results with Worcester Pearmain on clonal rootstocks. *J. hort. Sci.*, **34**, 32-8.

(9) Rogers, W. S. (1927). Rootstock effect on colour and size of apples. *Rep. E. Malling Res. Sta. for 1925*, **II**, 16-32.

(10) Sewell, G. W. F., and Wilson, J. F. (1959). Resistance trials of some apple rootstock varieties to *Phytophthora cactorum* (L. and C.) Schroet. *J. hort. Sci.*, **34**, 51-8.

(11) Tydeman, H. M. (1953). A description and classification of the Malling-Merton and Malling XXV apple rootstocks. *Rep. E. Malling Res. Sta. for 1952*, 55-63.

SOME TRIALS OF THE EFFECT OF DEFOLIATION UPON CROPPING OF APPLES

By MOYA H. E. DAVIES

The biennial cycle in cropping is often initiated when a tree carries an excessively heavy crop in any one year, as for example when blossom in the previous year has been seriously damaged by frost. Measures to prevent over-cropping usually consist in reducing the crop in the ' on ' year by thinning either the fruit buds, the blossom, or the fruit. Fruit bud formation is, however, initiated in the summer of the previous ' off ' year, and a control measure designed to prevent the production of excessive numbers of fruit buds in the first place would be advantageous. The processes involved in the initiation of fruit buds are not fully understood, but the consistently large differences between the total leaf area of fruiting and vegetative spurs (1, 6, 8), suggest that this is intimately connected with the problem. In the past, stress has been laid chiefly on the maintenance of a high leaf area in the fruiting year (2, 3); the observations of Roberts (4, 5) that defoliation reduces fruit bud formation for the following year have apparently not been adapted for practical use in the non-fruiting year.

Preliminary trials at East Malling (7) of the effect of defoliation of a biennial bearing apple variety in the ' off ' year established that recovery from defoliation was rapid if it was done before the beginning of June ; later defoliation led to a more permanent reduction in the total leaf area, but had less effect on shoot growth. There were indications that severe defoliation at a suitable time would be likely to reduce fruit bud differentiation.

The defoliation trials described below were designed to test whether defoliation of apples in the ' off ' year can sufficiently reduce the crop in the next to make it practicable as a control measure for biennial bearing. The varieties chosen were Winter Sunshine (a biennial variety)* and Worcester Pearmain, which was chosen because it was thought that any effect of defoliation of such a regular cropping variety might be more pronounced than in a biennial one.

Partial defoliation of whole trees of Winter Sunshine

The following four treatments were allotted at random to 16 20-year old cordon trees, so that each treatment was replicated four times.

Treatment A — Early and late defoliation
B — Early defoliation only
C — Late defoliation only
J — Control (untreated)

Method

The early defoliation was carried out on the 8th May 1948, all leaves except the youngest at the growing tip being removed by hand from each spur or shoot. The late defoliation was carried out a month later, on the 8th June, by which time all the leaves were at least partially expanded.

Counts of the number of leaves removed from a selected tree at each time of defoliation gave the following figures :

First time of defoliation—Treatment A —4,867 leaves
B — 4,470 leaves
Second time of defoliation—Treatment A —3,223 leaves
C —7,484 leaves

These figures indicate the relative severity of the various treatments. Treatment C (late defoliation) was the most drastic single treatment, but treatment A (defoliation at both times) removed the greatest total number of leaves.

The number and area of leaves on selected spurs were recorded at weekly intervals from late April until the end of autumn leaf fall in 1948. Crop weights and the number and weight of shoots removed in pruning were also recorded, and fruit buds were counted in 1949.

Development of foliage

All treatments severely reduced both the number and area of leaves in the year of treatment. Treatment A (early and late defoliation) caused the most drastic reduction in leaf number and area,

* Winter Sunshine is M.XI rootstock—the only Malling apple rootstock with an edible fruit of good size : it is little cultivated as a scion variety, but was used for these experiments because a row of very biennial cordon trees was available. Further details of the variety are given in H. V. Taylor's ' Apples of England '.

followed by treatment C (Fig. 1). This result corresponds with the relative severity of the treatments as indicated by the counts of numbers of leaves removed.

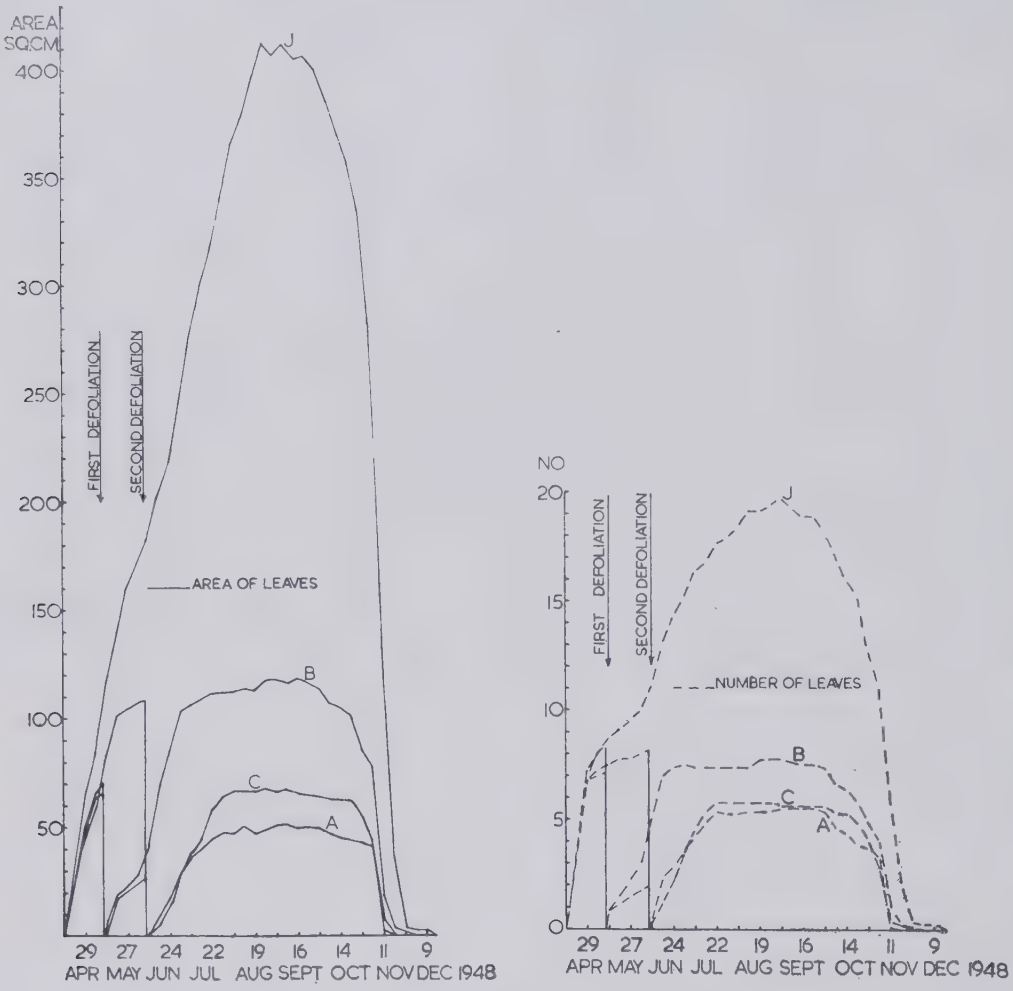

FIG. 1

Average number and area of leaves in defoliated and control (untreated) spurs of Winter Sunshine during 1948 (the year of treatment)

A—Early and late defoliation
B—Early defoliation
C—Late defoliation
J—Control (untreated)

Cropping performance

In the spring of 1949 the number of fruit buds was considerably and significantly less in treatments C and A than in treatment B (early defoliation only) and the controls (Table I). The order of reduction was the same in respect of the number and weight of fruit, but did not correspond exactly with the actual reduction in leaf number or area in 1948. All treatments resulted in significant reductions in the number of fruit, but the differences in weight, though large, were not significant except in treatment C.

Shoot growth

Significant differences were found in the number and weight of shoots removed in pruning in the winter of 1948-9, and in the number and length of shoots in the winter of 1949-50. All the defoliations reduced the number and weight of prunings removed in the winter following treatment, but the degree

TABLE I

EFFECT OF DEFOLIATION UPON AVERAGE NUMBER OF FRUIT BUDS AND AVERAGE NUMBER AND WEIGHT OF FRUIT IN 1949—VARIETY WINTER SUNSHINE

Treatment	Number of fruit buds	Number of fruits*	Weight of fruits* (lb.)
C(late)	24	37	5·9
A(early and late) ..	33	69	7·9
B(early)	186	121	8·4
J(control)	208	184	13·2
Sig. diff (P = 0·05) ..	79	62	6·0

* Picked fruit only

of reduction (Table II) did not correspond exactly with the relative reduction in leaf area in the growing season. It does correspond with the subsequent crop, already discussed.

TABLE II

EFFECT OF DEFOLIATION UPON AVERAGE NUMBER AND WEIGHT OF PRUNINGS FEBRUARY 1949—VARIETY WINTER SUNSHINE

Treatment	Average weight (gm.)	Average number
C (late)	240	73
A (early and late) ..	260	71
B (early)	350	72
J (control)	930	120
Sig. ratios* ..	3·0	2·1

* For the purposes of statistical analysis the data have been transformed into logarithms

Shoot growth measurements taken in the autumn of 1949 showed that the defoliated trees had made a little more than half the growth of the controls, but there was little difference between the three defoliation treatments.

Leaf cutting and defoliation of Winter Sunshine, 1948

A further trial was planned to test the effect of removing only certain portions of the leaves. In this experiment the lamina was subdivided into two main zones -the upper or distal half, and the lower or proximal half, using sister trees to those described above and the same controls.

The leaf cutting was carried out at the same time as the partial defoliations, on the 11th-13th May 1948. Each spur was first stripped of all but two leaves so that the degree of defoliation would be comparable with the treatments in which whole leaves were removed. Each of these leaves was then cut in accordance with the treatment laid down. There were six treatments including the untreated control, with four replicates, randomized among 24 trees :

D—removal of all except the distal halves of two leaves per spur
E—removal of all except the proximal halves of two leaves per spur
F—removal of all except the longitudinal halves of two leaves per spur
G—removal of all growing points
H—removal of all except the growing points
J—control (untreated)

In treatment E the proximal halves were removed by cutting along each side of the midrib to the half-way point. In treatment G growing points were removed $\frac{1}{4}$ in. from the tip, and in treatment H the trees were stripped of all leaves. Treatment F was included to allow for any effect due either to the reduction in leaf surface or to trauma ; in this treatment one left and one right half of each pair of leaves were removed on each spur.

Following treatment G, there was rapid replacement of each growing point, sometimes by as many as three new shoots. Since continued removal of these would only have led to a further

increase in the number of shoots and leaves, the trees in G and H were allowed to recover without further treatment. In treatments D, E and F however, the spurs were maintained at a constant two half leaves until the beginning of August, after which new leaves were allowed to develop ; these treatments were thus the most severe in this series.

Cropping performance

Large and highly significant differences between treatments were found in the number of fruit buds and number of fruits in 1949 (Table III). There were no significant differences between the various leaf cutting treatments D, E and F, nor between treatments G and H, but there were between these two sets of treatments, possibly due to the differences in intensity of the treatments. The differences in the weight of the fruit were not significant except in treatments E and F, an increase in the size of individual fruits probably compensating for reduction in number.

TABLE III

EFFECT OF LEAF CUTTING ON AVERAGE NUMBER OF FRUIT BUDS AND AVERAGE NUMBER AND WEIGHT OF FRUIT—VARIETY WINTER SUNSHINE

1949	Number of fruit buds	Number of fruits*	Weight of fruit (lb.)*
E (distal halves removed) ..	7	21	3·1
D (proximal halves removed) ..	24	69	8·0
F (longitudinal halves removed)	44	73	7·0
H (leaves removed)	86	113	10·8
G (growing points removed) ..	145	122	10·2
J (control)	208	184	13·2
Sig. differences P = 0·05 ..	79	62	6·0

* Figures refer to picked fruit only

Shoot growth

Differences between treatments in the number and weight of prunings removed in February 1949 were highly significant. In the following winter, highly significant differences were again found in the number of new shoots and significant differences in shoot length (Table IV). Treatment D (proximal halves removed) resulted in the greatest reduction in the number and weight of shoots produced in 1948, and number and length of shoots in 1949.

In both years the number of shoots differed significantly between treatments D and E but not between D and F. As previously noted, treatment G resulted in an increase in the number of shoots in both years, compared with the controls, but this difference was not significant.

TABLE IV

EFFECT OF LEAF CUTTING UPON SHOOT GROWTH IN 1948 AND 1949—VARIETY WINTER SUNSHINE

Treatment	Pruned in February 1949		New shoots in 1949	
	Number of shoots	Weight of shoots (gms.)	Number of shoots	Length of shoots
D	21	30	56	1,370
E	50	54	115	2,900
F	42	39	86	2,240
G	190	550	210	5,370
H	44	310	83	2,480
J	120	930	205	5,690
Sig. ratio*	2·1	3·0	1·9	2·2

* For the purposes of statistical analysis the data have been transformed into logarithms

Comparison of the results in Tables III and IV shows that in every instance cropping performance was influenced most by treatment E and shoot growth by treatment D. The only significant differences between these two treatments were in the number of shoots produced in 1948 and 1949, and in no case did either treatment differ significantly from treatment F. The regular pattern of the effects of

the various treatments upon vegetative and fruiting processes, however, suggests that these results are neither fortuitous nor due solely to the wounding of tissues. Since treatment F also involved the removal of part of the distal and proximal halves of the lamina, its effect would be expected to approximate closely to D and E ; its effect on shoot growth was in fact intermediate between them.

Partial defoliation of whole trees of Worcester Pearmain

This trial was carried out at the same time as the one previously described with Winter Sunshine and treatments were similar. The trees were 18-year-old dwarf bushes of Worcester Pearmain on M.IX, and there were four treatments with four single tree replicates :

Treatment A —Early and late defoliation
B —Early defoliation only
C —Late defoliation only
J —Control (untreated)

The first defoliation, on 8th May, was carried out ten days after full bloom. At the late defoliation it was found to be much easier to remove the leaves from the trees which had already been defoliated once.

Development of foliage

Treatment C had the most dramatic and prolonged effect comparable with that of Treatment A on Winter Sunshine. The trees recovered rapidly from early defoliation (Treatment B) whether this was followed by late defoliation as in Treatment A or not, and by early July their leaf area was larger than that of the untreated trees (Fig. 2). It is noteworthy that autumn leaf fall began earlier and was more gradual in the controls than in any of the treatments.

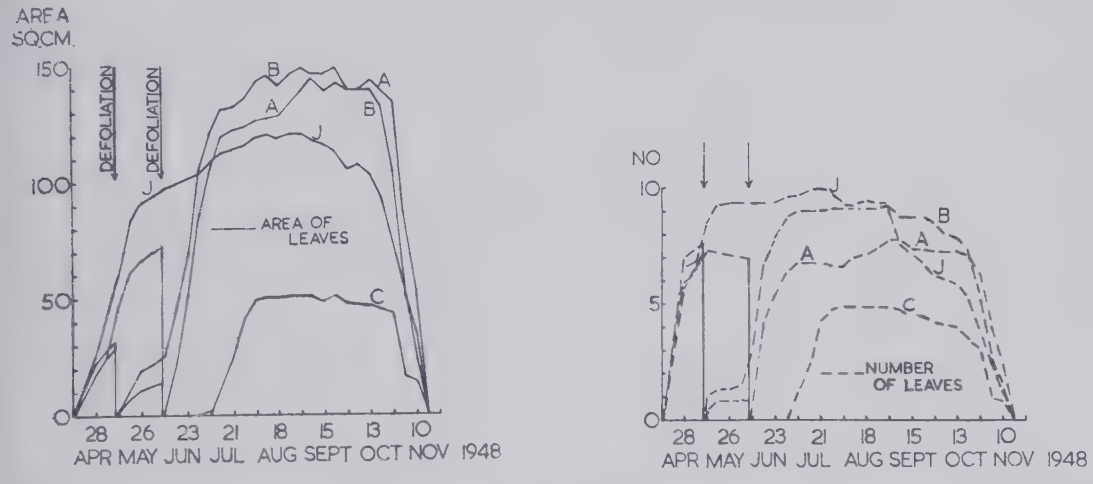

FIG. 2

Average number and area of leaves on defoliated and control (untreated) spurs of Worcester Pearmain during 1948 (the year of treatment)

A—Early and late defoliation
B—Early defoliation
C—Late defoliation
J—Control (untreated)

Cropping performance

The effect of early defoliation was evident in the amount of shedding which had occurred ten days after the treatments : nearly all the fruitlets on the treated trees had shed by this time so that the controls were the only trees to bear a crop in 1948. In the following years, however, there were no significant differences between the crops of any of the treatments (Table V).

Shoot growth

All the treatments appeared to reduce the number and weight of prunings in the two winters following treatment, but none of the differences was significant.

TABLE V

THE EFFECT OF DEFOLIATION UPON CROPPING AND FRUIT BUD FORMATION IN 1948 AND 1949—VARIETY WORCESTER PEARMAIN

	1948		1949		
	Number of fruits	Total weight of fruits (lb.)	Number of fruit buds	Number of fruits	Total weight of fruits (lb.)
A (early and late) ..	0	0·0	943	602	58·2
B (early)	5	0·6	916	601	58·2
C (late)	0	0·0	533	590	53·3
J (control)	303	42·8	610	577	54·5

Discussion

These trials have shown that the success of defoliation as a method of reducing fruit bud formation depends largely on its timing. In all the trials, defoliation approximately six weeks after full blossom reduced cropping and shoot growth in the following year far more than did earlier defoliation, or even early and late defoliation. This effect was also evident in the leaf cutting trial, which had the greatest degree of defoliation of any. Allowing only two half leaves per spur from May until early August might well have been expected to lead to a greater reduction of fruit bud differentiation and shoot growth. But a comparison of the whole leaf treatments of Winter Sunshine (A, B and C) with the half leaf ones (D, E and F) shows that the differences are not always significant. Thus, a late single defoliation is often comparable with the half leaf treatments, and distinct from the effect of earlier removal (treatments B and H). This suggests that the continuation of defoliation is less important than the fact that it was done at a later date.

The trial with Winter Sunshine showed clearly that severe defoliation can greatly reduce the growth and subsequent cropping of trees of this variety. This contrasts with the results of similar treatment of Worcester Pearmain which showed no significant effect either on the fruit buds and shoot growth in the year of treatment, or in the crop the following year. From this it would appear that the inherent regularity of bearing of Worcester Pearmain is difficult to influence, and even complete removal of the crop in one year does not initiate a marked biennial rhythm.

The drastic effect of late defoliation alone, as compared with early defoliation, either alone or in conjunction with a second defoliation, was somewhat unexpected. The fact that it was more difficult to remove leaves from Worcester Pearmain trees being defoliated for the first time at the later date suggests a possible explanation : the growing points of trees receiving treatment C had ceased producing new leaves, whereas trees which had already received one defoliation, had newly differentiated leaves and the meristematic tissues were presumably more active, so that these trees recovered more quickly from the second defoliation.

The defoliation of trees by hand is not a practical method of controlling biennial bearing in apple trees, but chemical sprays for this purpose have been tried already with promising results.

Acknowledgements

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Summary

Hand defoliation of all expanded leaves of the apple variety Winter Sunshine approximately forty days after full bloom reduced fruit bud formation, leaf area and shoot growth for the remainder of the season. Similar defoliation ten days after full bloom did not depress fruit bud production significantly, and the effects on leaf area and shoot growth were less severe. There is a suggestion that the removal of the distal half of the leaf has a greater depressing effect upon fruit bud production and allows more shoot growth than the removal of the proximal half.

Defoliation of Worcester Pearmain apple trees resulted in the dropping of the entire crop shortly after treatment ; shoot growth and cropping were not affected in the year after treatment.

REFERENCES

(1) DAVIES, M. H. E. (1952). Biennial and regular bearing in the apple. Thesis presented for the Degree of Ph.D. in the University of London.

(2) Haller, M. H., and Magness, J. R. (1926). The relation of leaf area to the growth and composition of apples. *Proc. Amer. Soc. hort. Sci. for 1925*, **22,** 189-96.
(3) ——— (1933). Relation of leaf area and position to quality of fruit and to bud differentiation in apples. *Tech. Bull. U.S. Dep. Agric.*, 338.
(4) Roberts, R. H. (1921). Off year apple bearing and apple spur growth. *J. Pomol.*, **2,** 16-37.
(5) ——— (1923). Effect of defoliation upon blossom bud formation : American plum species. *Res. Bull. Wis. agric. Exp. Sta.*, 56.
(6) Singh, L. B. (1947). Studies in biennial bearing in apples. Thesis presented for the Degree of Ph. D. in the University of London.
(7) — — (1948). Studies in biennial bearing III. Growth studies in ' on ' and ' off ' year trees. *J. hort. Sci.*, **24,** 123-48.
(8) Swarbrick, T. (1928). Factors governing fruit bud formation –IX. Some observations upon the leaf area of spurs on biennially bearing apple trees. *Ann. Rep. Long Ashton Res. Sta.*, 23-38.

ROYAL SOVEREIGN STRAWBERRY CLONE M.415

By W. S. ROGERS and MURIEL G. FROMOW

In 1945 a Norfolk grower, Mr. A. G. D. Greenshields, reported that a strain of Royal Sovereign strawberry which he had imported from County Mayo, Eire, was yielding more heavily than the Malling clone M.40. He kindly supplied the Research Station with some plants, some of which were found, by graft-testing, to be virus free. A new clone was propagated, and three preliminary and three full scale field trials have been carried out, comparing its performance with the Malling clone. In general the new clone has given a superior performance, as described below, and accordingly after re-testing for virus it was released to the Nuclear Stock Association in 1957, for propagation and general distribution, as M.415.

Experimental procedure

As results from all six trials were similar, only the three full scale trials will be described.

Trial 1, planted in November 1949, contained six replicates of 24 plant plots, with plants at $1\frac{1}{2} \times 3$ ft.

Trial 2, planted in November 1950, contained 10 replicates of 24 plant plots, which were allowed to form matted rows.

Trial 3, planted in October 1955, contained eight replicates of 50 plants at $1\frac{1}{2} \times 3$ ft.

Fruit was picked in three grades, viz., 1 and 2, marketable fruit above and below seven-eighths inch diameter, and 3, all unsaleable fruit. The yield of the first three picks was used as an indication of earliness, and the percentage of Grade 1 fruits as a measure of relative size.

The Malling clone M.40 was re-cloned in 1948 as M.48 and again in 1953 as M.401 ; but for convenience the original clone and its re-selections are referred to as M.48 all through the following discussion.

Results

Annual measurements have shown plants of the two clones M.48 and M.415 to be alike in height and spread. Observations on time of flowering and on frost damage in 1957 showed no differences between the clones ; and no morphological differences have been found between them.

TABLE I

THE RELATIVE YIELD, FRUIT SIZE AND EARLINESS OF ROYAL SOVEREIGN CLONES M.48 AND M.415

Trial	Season	Marketable yield		Fruit size		Earliness	
		cwt./acre		Grade 1 as per cent of 1 + 2		1st 3 picks cwt./acre	
		M.48	M.415	M.48	M.415	M.48	M.415
Trial 1	1951 (2nd year)	58	57	69	63	9·3	8·8
	1952	34	40	47	42	9·3	8·7
Trial 2	1952 (2nd year)	53	57	30	28	7·9	6·0
	1953	84**	93	50	47	5·8	4·6
	1954	83	90	33	34	5·0	4·7
Trial 3	1956 (1st year)	8	9	60**	67	3·5	3·7
	1957	51***	72	27	33	6·1**	4·6
	1958	75	81	50	54	22·7**	17·3
	Mean	55·8	62·4	45·8	46·0	8·7	7·3

Yield figures are rounded off to the nearest cwt. (112 lb.)

*** Significance level $P < 0.001$

** Significance level $P < 0.01$

Marked differences in yield have been found, however, as shown in Table I. In all years but one, M.415 yielded more than M.48. The increase has varied from year to year, but in mean yield M.415

has exceeded M.48 by 11 per cent. Expressed another way, a grower with an acre of each would have had an average of about 7 cwt. more fruit per year from M.415 than from M.48.

The differences in yield have generally been greatest when growing conditions were best ; and it appears that when the yields from the two strains were nearly similar some other factors may have been limiting. Thus in Trial 1 the vigour of all plants was limited by re-infection with virus, and in 1952 the crop of Trial 2 was curtailed by drought.

Fruit from the two clones has shown no consistent size difference, but in Trial 3 M.415 tended to give rather larger fruits than M.48. Detailed records in 1957 showed that the increase in yield was due to increase both in size and number of fruits. No difference has been found in the appearance or texture of fruits of the two clones ; and a tasting panel found no difference in their flavour.

The first fruits of M.415 have been slightly later ripening, but the differences in amount at this time are small, and well outweighed by the increases shown in the later pickings (Fig. 1 and Table I).

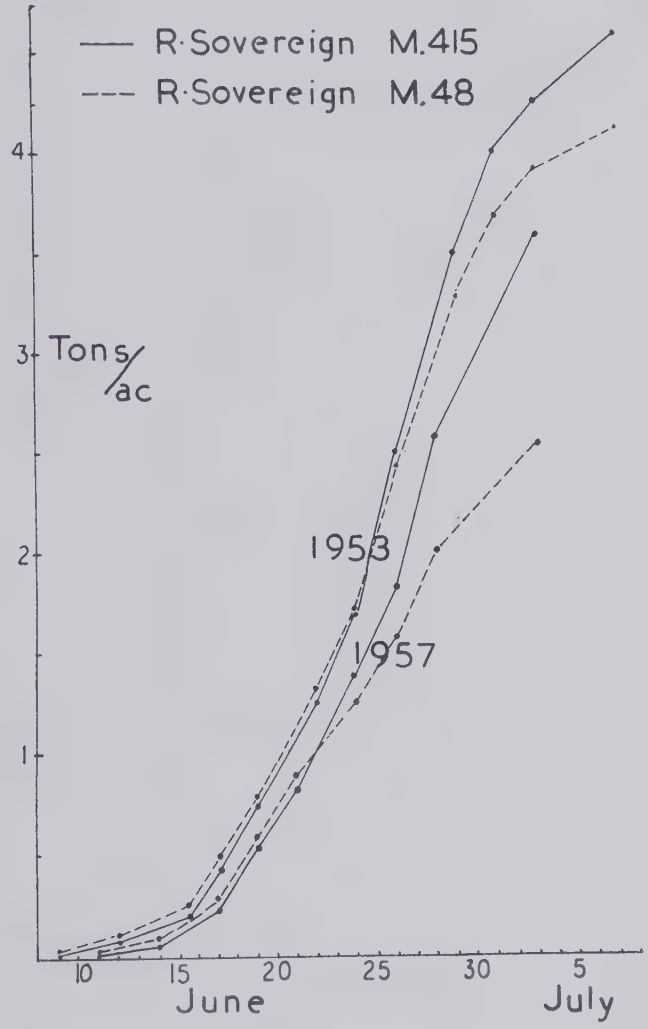


Fig. 1

Accumulated yield of Royal Sovereign, M.415 and M.48, in 1953 and 1957

At the present time, when emphasis tends to be placed on increased yield, often at the expense of fruit flavour, a heavier yielding strain of Royal Sovereign is particularly welcome. The results of these trials provide evidence of mutations of genes affecting yield, and re-emphasize the value of continuous selection for improved performance.

Acknowledgements

The authors thank Miss D. J. Wilson and Mr. R. I. C. Holloway for their collaboration in these trials.

Summary

The new clone of Royal Sovereign strawberry M.415 yielded 11 per cent more fruit than the clone M.48 in three replicated trials, over a period of eight years. The increased yield came mainly in the later picks, and from a longer cropping season. Both clones were indexed as virus free, and showed no difference in morphology or size of plant. The small but consistent difference in yield is considered as evidence of a mutation.

The clone M.415 is now being propagated by the Nuclear Stock Association.

WEATHER CONDITIONS DURING 1958

By G. F. TROWELL

East Malling Research Station

The past year will best be remembered for consistently bad weather during the summer months when extremely dull wet conditions were experienced. Six days in July provided the longest dry and reasonably hot spell during the summer. Although thundery conditions contributed to the excess rainfall at East Malling, far worse storms brought abnormally heavy rain and hail to many parts of Kent, some within a comparatively short distance of this Station.

Sunshine during the year amounted to 1,359·8 hours, 203 hours below the 25-year average, and 238·3 hours below last year's total. July, September, and October were the only months to have sunshine above average. It was the dullest June since 1923 with 90 hours below average, less than half that in June 1957. July was the sunniest month of the year with 213·8 hours. August on the other hand was the dullest since 1922, and it is interesting to note that the total sunshine in April was more than in either June or August. Sunshine in September brought some relief to an extremely dull summer. There were 16 days in November when no sunshine was recorded (9 consecutive), and 61 days throughout the year.

The total rainfall during the year was 30·52 in., 3·79 in. above the 35-year average and the wettest since 1951, when 35·81 in. of rain fell. Although wetter than recent years March and April were once again below average ; during the past six years, both March and April have been below average five times. June was the wettest month of the year with 3·93 in., falling on 19 days, over twice the average rainfall for this month ; the heaviest day's rainfall of 1·09 in. occurred on 19th June. July was the driest month of the year, its total of 1·16 in. being recorded on as many as 15 days. The total rainfall for August was 3·82 in., the wettest since 1946. During May, June, and August, 9·78 in. was recorded, the largest amount during this period since records began in August 1914, the previous highest during this period being 9·63 in. in 1946. Rainfall during October was well above the average, while November, usually the wettest month, was comparatively dry. The year ended with the wettest December since 1945. Rain fell on 190 days throughout the year.

Temperatures generally were above average for the first two and last three months, and below average from March to the end of August. Mean air temperatures in February were 2·5° F. above average, while March was 3·1° F. below average. September had the highest mean air temperature since 1949. Mean maximum screen temperatures in February were well above average, but from March to the end of August they were below, although from May to August inclusive they were not so low as in 1955 and 1956. The highest screen temperature in 1958 was 81° F. recorded on 8th July and 5th September, compared with 92° F. recorded last year. Mean minimum screen temperatures during January and February were above average, with March, April, May, and June all below average. The lowest screen temperature of the year was 17° F., recorded on 11th March, the lowest screen temperature in March since 1947, and the 25° F. recorded in April was the lowest for this month since 1938. Mean minimum temperatures during the latter half of the year were all above average. The lowest screen temperature in October, 35° F., was the highest minimum for this month since records began.

Spring was later than last year, 1957 being extremely early. Although Myrobalan B started flowering 18 days earlier than the average, full blossom was only one day early ; indeed after an early start most varieties flowered at the normal time, the long cold spell in March and early April obviously checking blossoming (Fig. 1).

The cold north-easterly winds which usually occur throughout much of April and sometimes into May, were earlier this year and less frequent, affecting only late Myrobalan blossoms, and early flowers on gooseberries ; conditions were thus generally good for pollination.

Ground frosts were more numerous than last year (82 compared with 70) but fewer than in 1955 and 1956, the largest number occurring in March. No serious late spring frosts occurred this year. The first autumn frost was not until 1st November.

Thunderstorms were more frequent than usual, being recorded 13 times over or in the neighbourhood of the Station, during February, April, May, June, July, August, September, and October. Considering the number of thunderstorms which took place, the actual amount of rain occurring during some of these storms was small. Only 0·10 in. was recorded at East Malling during the freak storm which hit the Sevenoaks area on 5th September, where up to 5 in. was recorded.

Snow or sleet was recorded 24 times, during January, February, March, April, and December, the ground being snow covered on 16 occasions ; the greatest depth was 6 in., on 24th January.

Table I

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1958

East Malling

Month	Temperature in Screen (°F.)					Number of Ground Frosts	Rainfall (in.)			Sunshine (hours)			Soil Temperatures (°F.)			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total	Heaviest fall in a day	35 years' average	Total	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	44·2	33·2	56	14	38·7	17	2·77	0·47	2·46	45·5	1·5	47	36·8	38·2	40·1	42·9
February	48·1	35·9	57	27	42·0	10	2·45	0·59	1·95	39·8	1·4	68	39·8	40·8	41·9	42·8
March	45·9	33·0	59	17	39·5	19	1·39	0·35	1·57	116·8	3·8	123	37·6	38·8	40·5	42·2
April	53·4	37·8	72	25	45·6	7	1·43	0·68	1·90	139·4	4·6	152	45·0	44·1	44·8	44·1
May	62·1	43·5	77	30	52·8	1	2·03	0·66	1·93	188·1	6·1	200	55·8	53·7	53·5	50·4
June	66·2	48·3	78	40	57·3	0	3·93	1·09	1·63	132·2	4·4	222	61·3	58·4	58·2	54·9
July	70·7	52·7	81	43	61·7	0	1·16	0·24	2·25	213·8	6·9	208	64·6	62·9	62·5	58·7
August	69·4	52·5	80	43	61·0	0	3·82	1·04	2·35	127·9	4·1	194	62·2	61·4	61·9	59·7
September	68·2	51·6	81	36	59·9	0	2·50	0·64	2·18	157·0	5·2	147	59·2	59·4	60·8	59·8
October	59·3	45·7	63	35	52·5	0	3·92	0·84	2·85	112·0	3·6	105	51·2	52·2	54·4	55·8
November	49·1	38·6	57	26	43·9	11	1·49	0·64	3·18	45·9	1·5	55	42·9	44·7	47·7	50·9
December	47·0	35·5	56	28	41·3	17	3·63	0·54	2·48	41·4	1·3	42	39·1	40·7	42·9	45·9
Totals						82	30·52		26·73	1,359·8		1,563				

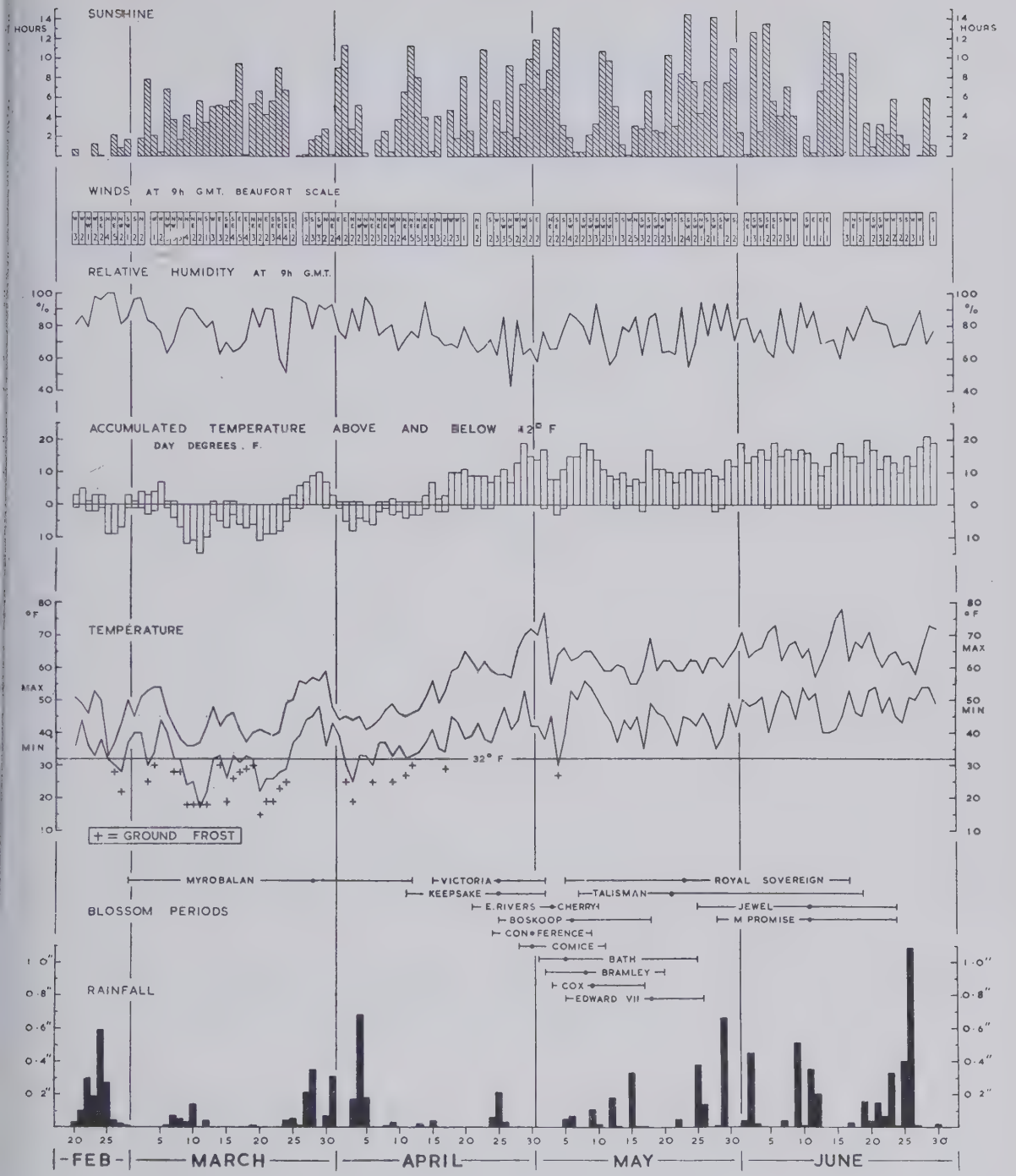


FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling Research Station in 1958

Once again no appreciable amounts of snow fell in the second half of the year, only one slight snow shower falling on 15th December.

Fog was experienced more often than in recent years, occurring 46 times, during January, February, March, August, September, October, November, and December. Fog was recorded 12 times during November, the foggiest month.

Ground conditions were fairly good for spring planting in early and late March, the ground being frozen on six occasions during the middle of the month. Dry ground was experienced throughout much of April and May. Soft muddy wet ground occurred during much of November and December. Dry ground conditions were not recorded once from 15th September to 31st December.

Acknowledgements

The writer wishes to thank Mr. C. H. W. Slater for his assistance during the year.

STATISTICS AND RECORDS

A REVIEW OF EXPERIMENTAL DESIGN AT EAST MALLING, 1953-1958

By S. C. PEARCE and G. H. FREEMAN

Introduction

Two earlier papers in this series (10, 11) have reviewed progress in the use of statistical designs for experiments with perennial plants up to 1952, giving considerable attention to the application of new classes of design. Interest in both the theoretical and applied aspects of new designs has continued at East Malling, recent papers having been concerned with circumstances in which existing designs can be best used for successive experiments (5), with descriptions of new designs and their analysis (1, 7) and with enumerating the various designs of one type (2). Meanwhile, a general review of the application of known designs to experimentation with perennial plants was published (6). The position nowadays is that the design of a particular experiment is rarely limited solely by statistical considerations, and so emphasis has been laid more on the relation between the purpose of a trial and its lay-out.

In this paper the designs of various experiments are described, showing the way in which the purpose of the trial has influenced its design. During the period under review changes in the technique of field experimentation have required corresponding alterations in trial design, but no new designs are described here. Where trials described in the two earlier reviews have been found to be less than wholly satisfactory it is generally on account of undue complexity, combined sometimes with an insufficient appreciation of the purpose of the trial. One instance is the apple rootstock trial, planned in 1945 (10), in which provision is made, by a restriction on the randomization, for thinning the trees. This is an admirable design, whose complexity has caused no real difficulties in analysis. However, it is already evident that not all the rootstocks are of equal value, and so interest is concentrated on only a few. It is desirable to carry out analysis of the results of just these few, but the restriction on the randomization tends to make such analyses not fully valid. The trees may yet be thinned, but it will probably be better to carry forward the best stocks to a further trial and not continue this one much longer. Whereas it could not have been foreseen when the trial was started which would be the best stocks, it has become apparent that with so many the trial cannot be a final one and so will not last long enough to require thinning.

Two of the trials to be described here also suffered slightly from having designs too complex for the purpose, while the reverse has never been found. The more types of design available the better, but the complex ones should never be used just because they look good on paper. In general, it has been found at East Malling that complicated designs should be used for trials lasting only a few years at most, as the natural hazards of many years' experimentation are more serious on a design not initially simple.

During the period there has been a general tendency to increase the degree of replication, but it should be recognized that this is an expensive expedient for combating inaccuracy. The approach should lie in better material or in better knowledge of how to calibrate it. It is also possible that an insufficient appreciation of the best plot size has led to waste of material.

Block and plot size

In general, planning has proceeded on the assumption that variation arises from differences inherent in the plants rather than from positional effects, though with better knowledge of certain positional differences to be expected at East Malling (4, 8, 9). Accordingly, in the absence of such known differences, little effort is made to keep blocks small if any advantage can be seen in making them large. Thus, numbers of small trials are designed without any division into blocks at all, where otherwise there would be too few degrees of freedom for error ; other trials are often planned with two replicates to a block, especially if this will facilitate the addition of a further factor later. Again, plot size is not usually chosen solely to minimize positional variation. However, single plants are preferred whenever the experiment deals with fundamental problems of growth or cropping, although such small plots are rarely practicable if they have to be guarded. On the other hand, in the variety trials designed for the National Fruit Trials at Faversham, four-tree plots of top fruits have been adopted as giving a better chance of detecting varietal characteristics.

With strawberries it is now clear that larger plots give nearly as much information per unit area as smaller ones (12) and are easier to record. Consequently 48-plant plots are now usual compared with 24 a few years back. With raspberries there has been an opposite tendency : plots now commonly consist of about 30 ft of row, whereas ten years ago they were often twice as large. With black currants too, smaller plots are now usual, six bushes being considered enough, provided cultural operations can be carried out.

One point of increasing practical importance has been the elimination or reduction of the number of guard plants with soft fruits, especially with strawberries. The separate picking of plants at the end of plots is particularly time-consuming, and the present tendency is to use cross-alleys instead.

Further experience has been gained with plots so small that several of them go to a tree, e.g. use of branches as plots, the whole tree being the block. Where the effect of treatments is strictly local this is a useful device : new techniques (7) now make it possible to test this initial and crucial assumption, i.e. whether treatments are thus confined in their effects and whether their remote effects, supposing there to be any, depend upon the treatments applied elsewhere on the tree. However, estimation of the differences between trees is of such importance in the statistical analysis that many trees are needed. The position is, therefore, not that less plant material is needed for an experiment but rather that more information can be obtained from the same amount.

Trials with some systematic element

When there are several factors in a trial the main effects of some may well be of no interest, and these can then be arranged systematically. The commonest use of this practice at East Malling has been to plant whole rows of scion varieties, to facilitate ease of picking and obviate difficulties of pollination. The idea is not new, since for many years varieties have been planted in rows, although this has sometimes meant sacrificing information on important comparisons. More recently, however, such trials have been so designed that it has been possible to examine the interactions of systematic and random effects, where these are the most important. Several varieties are introduced solely in order that treatment effects can be observed on different kinds of tree.

One set of trials, each with several varieties, has been planted to assess the effects of viruses on growth and cropping of various top fruits. The first trial to be laid down was on cherries and had a partially systematic arrangement by which the uninoculated control trees were intended as a permanent plant, regularly spaced, with the virus-inoculated trees around them. It was hoped that, when the virus trial was finished, the control trees could be used for another trial, but this prospect now appears unlikely. As this arrangement was unwieldy for its main purpose of assessing virus effects, subsequent virus trials, on plum, apple, and pear, have been planted on a rather simpler scheme. The trial on pears, laid down in 1957, is illustrated in Fig. 1 : in this, whole rows of varieties have been planted, with the virus treatments randomized within them, separately for each variety. By this means it will be possible to assess both the main effects of the viruses and their interactions with the varieties ; the main effects of varieties cannot be validly compared on these trials, but that will not matter. Trials of this type are economical in land, as the only guard trees necessary are on the headlands.

The same principle of systematic arrangement of varieties has also been adopted in a cherry and plum trial planted in 1956. There are cultural treatments on main plots, and each main plot contains six permanent cherry trees, with plums as guards and fillers. Fig. 2 shows one main plot and guards, with the uses of the various trees marked. The permanent trees form a 2×3 factorial of two rootstock and three scion varieties, the scions being planted systematically in rows across the whole area and the rootstocks arranged at random, separately for each row in each plot. The plum filler trees, of three different stock-scion combinations, are also arranged systematically. Thus, for cherry scions and plum varieties of both stock and scion, the only valid comparisons will be the interactions with the other factors.

For economy in land, all the guard trees of this trial are also used experimentally, the plums marking the boundaries of the main plots being used for trials of scion varieties and methods of staking. There is also a guard row of cherries and plums round the outside of the whole area one set each of cherries and plums being used for comparison of type of tree and another set of cherries for a rootstock trial. It is intended that when the trees come into cropping the remaining plums shall be used for a trial of sprays to control pre-harvest drop. Before the cherries fill the land the plums will come out. By then, however, information will have been obtained from them that would otherwise have needed separate land, while the main cherry trees in this trial would have had to have some guards and fillers.

As well as systematic arrangement of varieties there are other occasions on which something less than complete radomization is useful. It may be desirable to arrange different cultural methods

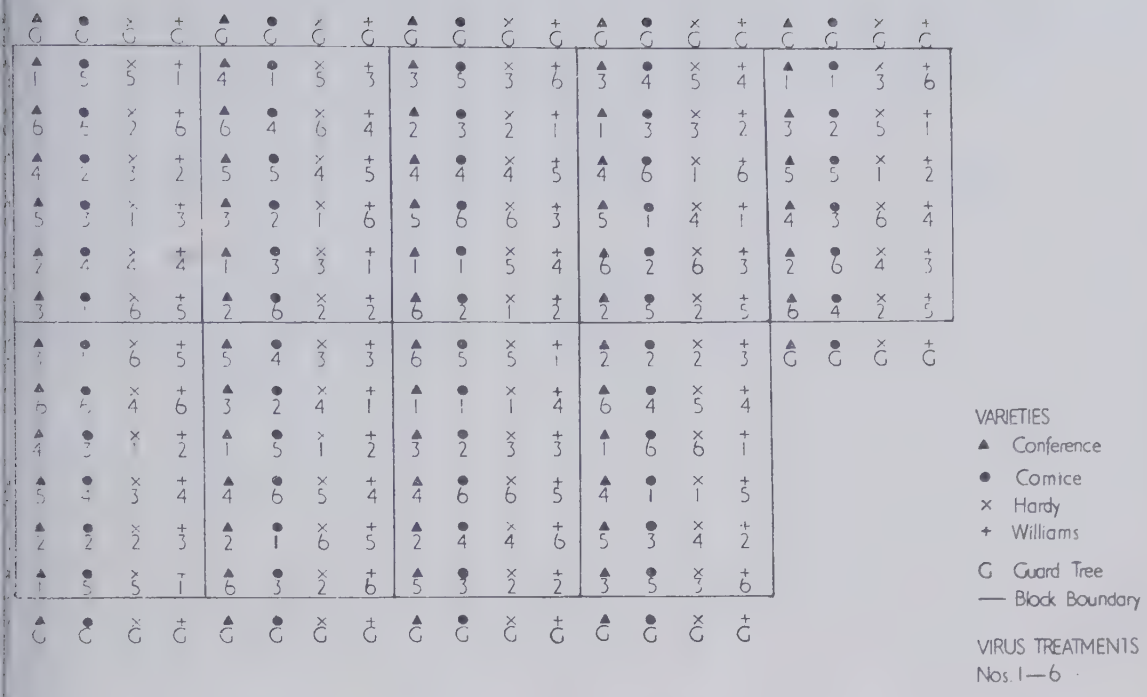


Fig. 1
Pear virus trial 1957

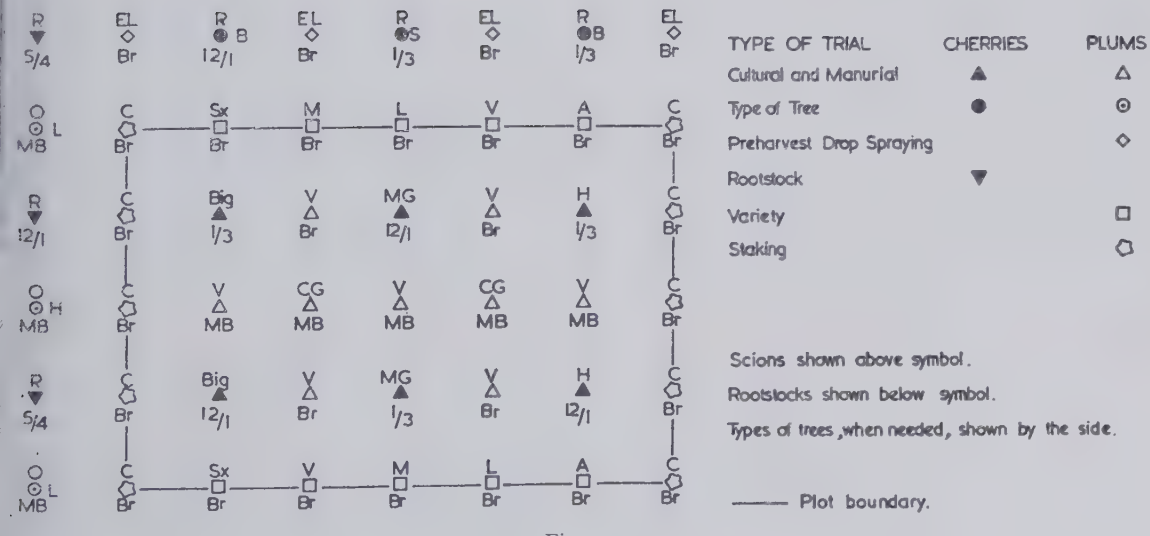


Fig. 2
Cherry and plum trials 1956
Plan of outside main plot with guards and fillers

across each other, as in a black currant irrigation trial planted in 1956, shown in Fig. 3. Here, the treatments are various amounts of water and rates of application of nitrogen ; for ease of management, each treatment is applied in strips, these being at right angles. Such a design may economize in guards, and is also particularly effective when, as here, assessment of the interaction between two sets of treatments is more important than that of their main effects, being also more accurate.

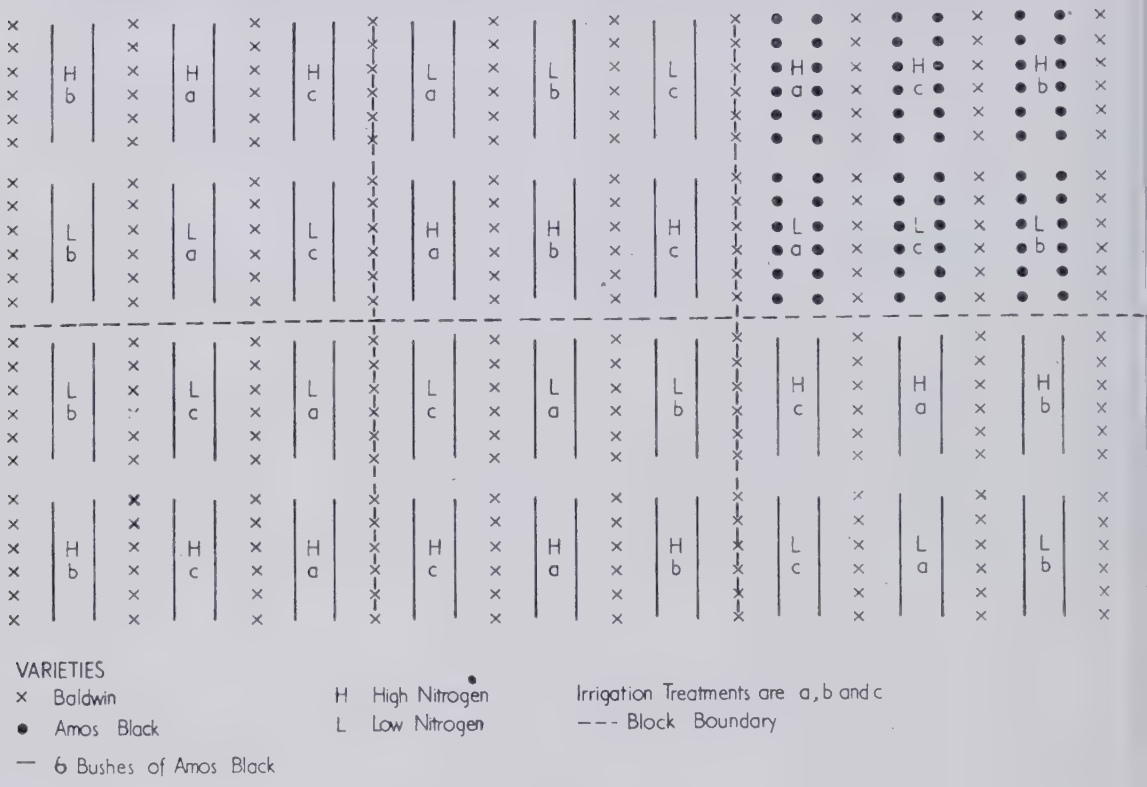


Fig. 3
Black currant irrigation trial 1956

Number of levels of a factor

With any factor the number of levels must depend upon the purpose of the investigation, special considerations arising when the differences between treatments are of a quantitative nature as with amounts of fertilizer, etc. If the intention is to find out if a certain factor has any effect at all it usually suffices to use two levels, one low and one high, but if it is accepted that there must be an effect of some sort and it is desired to obtain a response curve relating the effect of application to the quantity or concentration applied, the situation is more difficult. The usual method in the past has been to use three levels and to judge the shape of the curve from the effect of the middle level in relation to the other two. It is now questioned whether this is good enough ; if the curve is likely to have the form first suggested by Mitscherlich, four levels enable it to be examined fairly effectively though they are necessarily expensive in land and material. Nevertheless, a trial was conducted on the irrigation and nitrogenous fertilization of strawberries with four levels of nitrogen, the intention being to fit response curves for increasing applications of nitrogen, both under irrigated and unirrigated conditions.

Successive experiments

In the last few years considerable attention has been given at East Malling to both the theoretical (1, 2) and applied (3, 5) aspects of successive experiments on the same material. It is now regular practice here when designing a trial, particularly with spraying treatments, to consider the use of the material after the trial is finished. Even in cases where the same treatments are to be applied for a number of years there is usually the intention, whether well-defined or vague, to use the plots again. The red spider mite control trial described in an earlier review (11) was in fact used in a third year, 1953, in the way suggested in that paper, the effects of the 1952 treatments being of considerable importance in 1953.

Most successive spray trials here have been primarily concerned with phytotoxic effects of various chemicals on trees, rather than with effects on pests or diseases. In such trials sprays are applied at concentrations possibly higher than would be used for control measures, and so the risk of treatments having residual effects is quite high. The study of many such trials suggests that it is not uncommon for a spray treatment to have an effect in the year after that in which it was applied, while it is rare for effects to persist longer. There have been cases where some effects, usually of just one treatment, have been very severe, and then those trees have either been omitted from the next trial or the whole area has been rested. In most other cases, however, the effects of only one set of treatments have to be considered when the next set is applied, and many trials for this purpose have been designed. Most have been simpler than the red spider trial at Writtle mentioned above, and many have used the same treatments in several years. In such cases, the reallocation of the same spray treatments has afforded a means of distinguishing between direct and residual effects.

When spray treatments are not thought likely to leave residual effects, more complex designs can, if necessary, be used, although this is seldom desirable. One trial with too complex an arrangement of treatments had as its object the comparison of different methods of formulation of DDT for control of codling moth. The trial, including formulation controls, had 13 treatments and was replicated four times, the unit plot being a branch of a tree. This appeared to be satisfactory, as there was no reason to suppose any remote effects (7) of a treatment on a different part of the tree. However, the trees were blocks and the design was in balanced incomplete blocks, which, though suitable for assessing the effects on the insect population, proved most unwieldy in estimating amounts of DDT. Had the design been simpler there would have been no difficulty in considering some treatments only, but here it was very awkward to study just the seven DDT treatments. Thus, the advantages of the blocking were lost, and the trial serves as a warning against using a complicated design when not all treatments have to be considered for every record.

In general, if a particular plot size or system of guarding has proved unsuitable this can be altered in another year, if there are no residual effects. Thus, the trees in the DDT trial above were not used again until two years later, when residual effects had disappeared. Then, whole trees were unit plots.

Designs with unequal replications.

There are various cases where not all treatments need to be replicated to the same extent. Thus, controls may be introduced only to provide an indication that the other treatments are having an effect, these others being chiefly compared amongst themselves. In such a case there may be fewer plots of the control than of any other treatment. Alternatively, the purpose may be to compare each of a range of new treatments with an established standard, comparisons between them being for the moment of less importance. Here it is desirable to have a higher degree of replication for the standard treatment than for others ; indeed, it is now recognized that in such an event, for the most effective use of resources, the replication of the control should equal that of the other treatments multiplied by the square root of their number, e.g. if four treatments are to be compared with a common standard, each block should contain six plots, two for the standard and one for each of the others. Thus, the difficulties inherent in unequal replication can be overcome to some extent by relaxing the requirement that no treatment shall occur more than once per block.

A case where two treatments needed different replication from the others was a strawberry variety trial for the National Fruit Trials at Faversham. Here, there were two strains of Royal Sovereign and twelve other varieties. Each of the varieties other than Royal Sovereign had one plot per block, while in two of the four blocks one strain of Royal Sovereign was represented twice and the other once. In the other two blocks the first strain occurred once and the second twice, and so each block had fifteen plots, three in all of Royal Sovereign and one of each of the twelve other varieties.

Summary

Tendencies since 1952 in the application of experimental designs to practical problems at East Malling are reviewed, and some examples given.

References

(1) Freeman, G. H. (1957). Some experimental designs of use in changing from one set of treatments to another. Part I. *J. R. statist. Soc.*, **B**, 154-62.

(2) ——— (1958). Families of designs for two successive experiments. *Ann. math. Statist.* (in the press).

(3) FREEMAN, G. H. (1959). The use of the same experimental material for more than one set of treatments. *Applied Statistics* (in the press).
(4) FURNEAUX, B. S. (1954). The soils of East Malling Research Station. *Rep. E. Malling Res. Sta. for 1953*, 60-82.
(5) HOBLYN, T. N., PEARCE, S. C., and FREEMAN, G. H. (1954). Some considerations in the design of successive experiments in fruit plantations. *Biometrics*, **10**, 503-15.
(6) PEARCE, S. C. (1953). Field experimentation with fruit trees and other perennial plants. *Tech. Commun.*, **23**, *Bur. Hort., E. Malling.*
(7) ——— (1957). Experimenting with organisms as blocks. *Biometrika*, **44**, 141-9.
(8) ———, and GREENHAM, D. W. P. (1955). A short history of Research Station land in the parish of East Malling. *Rep. E. Malling Res. Sta. for 1954*, 54-63.
(9) ———, ——— (1957). A short history of Research Station land in the parishes of Ditton and Aylesford. *Rep. E. Malling Res. Sta. for 1956*, 49-53.
(10) ———, and HOBLYN, T. N. (1948). A review of experimental design at East Malling, 1919-1947. *Rep. E. Malling Res. for 1947*, 88-100.
(11) ———, JOLLY, G. M., and FREEMAN, G. H. (1953). A review of experimental design at East Malling, 1948-1952. *Rep. E. Malling Res. Sta. for 1952*, 83-7.
(12) TAYLOR, J. (1951). Statistical studies on strawberry crop and vigour records. *Rep. E. Malling Res. Sta. for 1950*, 100-7.

SOME RECENT APPLICATIONS OF MULTIVARIATE ANALYSIS TO DATA FROM FRUIT TREES*

By S. C. PEARCE

In this paper no attempt will be made to develop multivariate analysis mathematically. The purpose is rather to suggest that biological experimentation calls for multivariate methods, and to present some results of their application to data from fruit trees.

There appear to be two main criticisms of their use. One is to assert that an experimenter should be interested solely in crop, but this is to ignore the importance of knowing how the fruit is obtained. Thus, an increase in crop may have resulted from additional growth or may have been produced at the expense of growth. The two cases are different and need to be distinguished, but the differences are not to be found in the changes in the two variates separately but in the relationship between them.

The other objection to multivariate methods is rather different. It asserts that an experimenter is interested in his variates, e.g., trunk girth, extension growth, etc, and not in some function of them. At least where growth records are concerned, this appears to be a gross misunderstanding. No one, except a forester trying to produce wood, is in the least interested in trunk girth as such. It is needed rather as an indicator of growth, a factor that manifests itself in many variates and appears to do so to different degrees because the whole situation is confused by the operation of other factors, such as apical dominance. What is needed is a measure of the *factors* behind the phenomena, not of the *variates* to which the factors give rise. This is where multivariate methods can help, always provided that a biological meaning is sought at every point, and the methods are never used for their own sake.

At East Malling there are three studies in progress of multivariate methods in relation to fruit trees ; one is concerned with the chemical contents of leaves, one with crop records, and one with growth records. Only the last will be considered here.

Variates to be used

Essentially a tree grows in only two ways ; one is by shoot growth resulting from the activity of the apical meristem, the other by shoot thickening, resulting from the activity of the cambial meristem. It is clear that these two forms of activity do not always proceed proportionately, because pruning can lead to a stimulation of extension at the expense of thickening and it is known also that the balance depends upon the rootstock on which the tree is grafted. Bearing these two forms of activity in mind, four quantities were chosen, two measured at four years after planting and two at grubbing ; in each group one was of trunk circumference, i.e., the result of cambial activity, and the other was intended as far as possible to measure the other kind of activity, i.e., extension growth in the first four years and tree weight at grubbing.

Logarithms were taken of each of these four quantities. Practice with respect to transformation varies but the reasons here for working with logarithms appeared strong. For one thing, it was known that the quantities give straight-line relationships with one another only when raised to powers; for another, the factors, if any should be found, supposedly operate on growth rates rather than on actual sizes of the parts measured.

Next, each of the variates thus transformed was divided by its standard error, so that work proceeded with the correlation matrix, not the dispersion matrix. Again, practice varies, but in this instance there was reason to think that the relative standard errors were characteristics of the varieties and accordingly irrelevant to the investigation, and their effects better eliminated. Certainly the correlation matrices gave consistent results, which the dispersion matrices would not have done.

With these two transformations, four variates were obtained, w, g, l, and e, as set out in Table I.

TABLE I

THE VARIATES

$w = log$ (tree weight at grubbing)
$g = log$ (trunk circumference at grubbing)
$l = log$ (extension growth during the first four years)
$e = log$ (trunk circumference after four years)

All quantities are measured in terms of their own standard errors.

* Based on a paper presented in Brussels on 9th September 1958 at the Deuxième Journée de Biométrie, organized by La Société Adolphe Quetelet.

TABLE II

THE TRIALS FROM WHICH DATA WERE TAKEN

Trial	Variety	Form of tree	Age at grubbing	Treatments
A	Bramley's Seedling	Bush	16	13 rootstocks
B	Cox's Orange Pippin	Bush	19	2^2 NP manurial
C	Cox's Orange Pippin	Bush	23	2^2 NP manurial
D	Allington Pippin	Half-standard	33	9 rootstocks

Trial B received high potash dressings and Trial C low ones ; together they formed a 2^3 NPK factorial trial.

In Trials B and C there were four trees to a plot, a Cox's Orange Pippin and a Beauty of Bath on each of the rootstocks M.I and M.V. For most purposes only the Cox on M.I was used, but all four were used in evaluating the quantities in Fig. 1.

TABLE III

THE VECTORS

Trial	Vector	Coefficient w	g	l	e	Percentage of variation accounted for
A	V_1	+0·49	+0·52	+0·51	+0·48	79
	V_2	+0·56	+0·42	−0·44	−0·56	18
			Other vectors			3
B	V_1	+0·51	+0·55	+0·47	+0·48	58
	V_2	+0·50	+0·44	−0·55	−0·51	39
			Other vectors			3
C	V_1	+0·49	+0·55	+0·50	+0·46	63
	V_2	+0·55	+0·41	−0·48	−0·55	32
			Other vectors			5
D	V_1	+0·51	+0·50	+0·49	+0·50	61
	V_2	+0·49	+0·50	−0·52	−0·50	30
	V_3	−0·43	+0·41	−0·56	+0·57	6
			Remaining vector			3

Sources of data

Data were taken from four trials, which are briefly described in Table II. It will be seen that the trees were of different kinds, except for B and C which were originally part of the same experiment. Even here they differed considerably, because those with low potash were abnormal and stunted.

Results of component analysis

When the correlation matrices were subjected to a component analysis, the results were surprisingly consistent despite the marked differences between the trials in respect of fertilization levels, variety, and form of tree. In general, as is shown by Table III, there were two factors, a larger one having the vector :

$$\tfrac{1}{2}, \quad \tfrac{1}{2}, \quad \tfrac{1}{2}, \quad \tfrac{1}{2},$$

and a smaller having the vector :

$$\tfrac{1}{2}, \quad \tfrac{1}{2}, \quad -\tfrac{1}{2}, \quad -\tfrac{1}{2},$$

With the exception of one trial these two vectors accounted for 95 per cent or more of the total variation.

It may be asked how far these vectors have any biological meaning. The first of them can be taken to represent vigour, the tendency of a tree to make growth in all its forms. The second is no less obviously an establishment factor, a tendency for some trees to exceed their early promise and for others to belie it.

However, it remains to consider what effects, if any, the factors correspond to. In Fig. 1 are set out values for V_1 and V_2 obtained by taking four trees on each plot (only one per plot was used in working out the figures in Table III), evaluating $\frac{1}{2}(w + g + l + e)$ and $\frac{1}{2}(w + g - l - e)$ for each tree, and then adding these values to obtain the plot values shown. Further, to display trends, these plot totals are grouped into sets of four to give the figures in the smaller diagrams. In all instances the figures are adjusted so as to average zero for both High Potash and Low Potash parts of the trial.

It will be seen that values of the vector V_1 appear to be distributed in something like a random

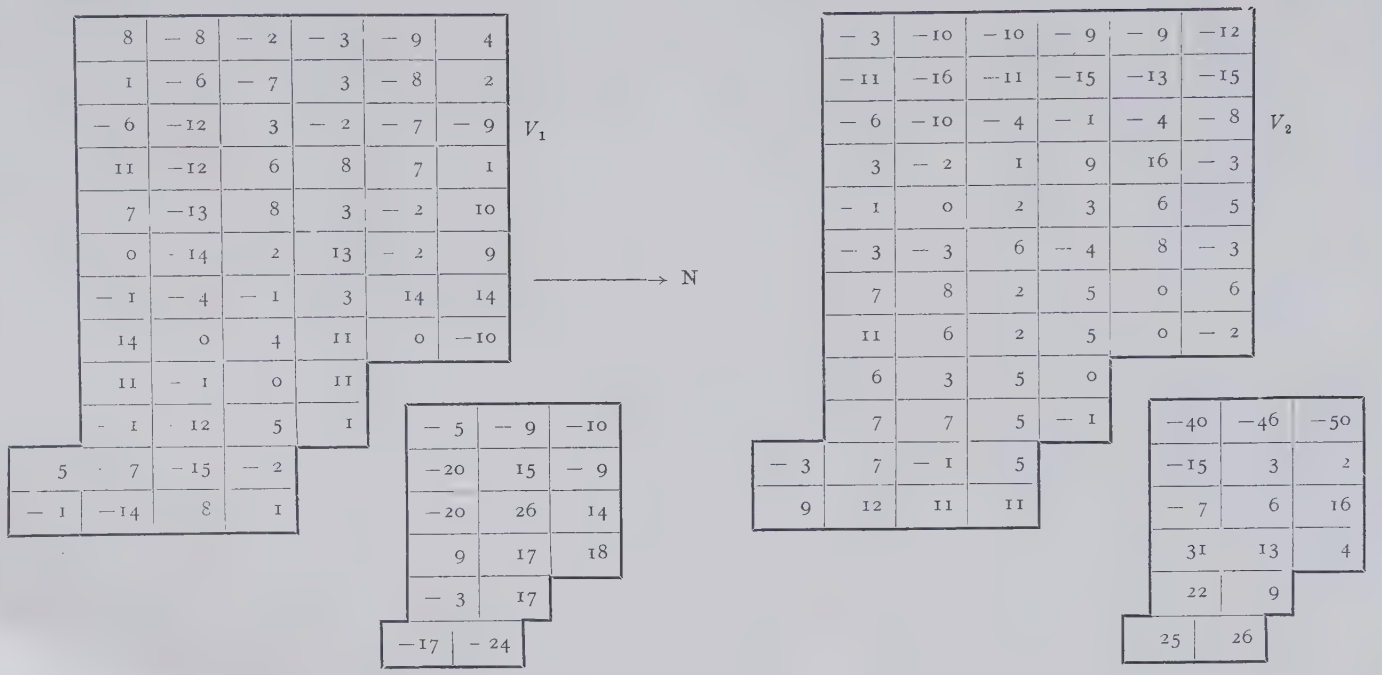


FIG. 1

Trials B and C

Values of V_1 and V_2 for each plot and for groups of four plots

manner. This is probably a consequence of the great variation inherent in the trees themselves, which is commonly so large as to make positional effects appear relatively unimportant. The other vector V_2, on the other hand, is no less clearly strongly positional.

Before considering V_2 further, it may be as well to describe briefly the soil of the area. It is a medium loam, much shallower at the west end than the east, and rather shallow along the northern boundary. Under this loam is limestone rock, but in some places, notably, so far as can be ascertained, at the western end and in a north-south band across the middle, the loam and the limestone are separated by a layer of ' pug ', a heavy clay rich in minerals. It is to be expected that subsequent development of the plant, and hence high values of V_2, will be associated with places where the growing tree can continue to deepen its root-system, and where the lower layers are of rich ' pug '. From the smaller figure it will be seen that, in fact, the lowest values of V_2 are to be found at the shallow west end, and the highest value of all at the south end of the band of ' pug ', where there was a reasonable depth of soil. It should be emphasized that this approach should not be pressed too far. Thus, the shallowest soil is in the south west corner, but this does not appear in the values of V_2 ; nor is the distribution of ' pug ' completely certain. Also attention has been given only to groups of four plots ; individual plots, and even more individual trees, are very variable.

It is, perhaps, worthy of note that the third factor in Trial D, represents a balance between apical and cambial activity, a result that could be expected from differential pruning among other treatments, and that this was the only trial in which the trees had been constrained to form a leg of constant length, being half-standards.

Discussion

The concept to which this leads is that of an error resulting from the action of two factors. Hence, if trees are plotted in a four-dimensional space of w, g, l, and e, they will all lie in a two-dimensional figure, i.e., on a plane. This means that error need not be regarded as an amorphous mass of uncertainty but as having a structure of its own. There are things it can do and things it cannot. It can move points representing trees around on the error-plane, it cannot lift them off the plane. Consequently each treatment effect can be divided into two parts, one perpendicular to the plane, plainly representing factors different from those comprised in error, and another part lying in the plane, representing factors already operative in the error together possibly with others already operative in the error together possibly with others that have a similar effect. Also, there are essentially two modes of growth in a tree, apical activity, which appears only in w and l, and cambial, which is shown rather by g and e. Any disturbance of the balance between these two forms will appear as a vector perpendicular to the error-plane, and accordingly should be readily detectable, because most error variation lies in the plane rather than across it. There are, of course, several kinds of treatment that might be expected to have such an effect.

This approach has not as yet led to any new knowledge, but it appears to be promising. It does present the tree as a living organism, a change in one respect resulting in concomitant changes elsewhere, and it does draw attention to the factors lying behind phenomena. In both these respects it may be accounted an advance on more established methods.

Summary

Reasons are given for the recent interest at East Malling in multivariate methods of analysing data, and some results are presented relating to tree growth. Two constant factors were isolated, one a general growth factor and the other a balance between size records taken early in the life of the trees and those taken at grubbing. The former factor appeared to be distributed at random, but the latter to follow soil characteristics.

STUDIES IN THE MEASUREMENT OF APPLE TREES
IV. THE USE OF BRANCH GIRTHS TO ESTIMATE TREE SIZE

By D. A. HOLLAND

In a previous paper of this series (3) the value of trunk girth as an estimate of tree size was discussed. In a later paper, however, attention was drawn to the fact that it is not always possible to measure trunk girth because the main crotch may be too low or the trunk damaged (4). In these circumstances an integration of the branch girths was suggested as a substitute on the basis of the high correlation found between this and trunk girth. The method of integration recommended was to divide the sum of the branch girths by the square root of their number, this quantity being written Q. It gives an approximation to the girth of a cylinder having the same area of cross-section as all the branches together.

In that investigation trees were ignored if main branches had been removed from them, though it was pointed out that this is especially likely to have happened where trees are so abnormal as to make records of trunk girths impossible. Actually, a figure based on branch girths could be expected to be better than the trunk girth as an estimate of tree weight in such circumstances, because the loss of a branch would reduce both Q and tree weight, but would not affect the trunk girth, at least, not for some years. On the other hand Q involves more measurements and the chance of encountering an abnormality such as a swelling or flaking bark would be correspondingly increased. When the opportunity arose through the grubbing of some completed apple trials it was decided to put the recommendation to an empirical test and this paper will describe the results.

Statistical approach

Adopting the notation of earlier papers in this series trunk girth will be written G, tree weight W, and the integration of the branch girths Q, where

$$Q = \frac{\text{sum of branch girths}}{\sqrt{\text{no. of branches}}}$$

Small letters will denote the logarithms of the corresponding capitals.

Correlation coefficients were worked out, for each set of data, between w and g on the one hand and w and q on the other. These correlation coefficients, r_{wg} and r_{wq} respectively, were then compared by a method described elsewhere (1, 2) for determining which of two variables is the better for predicting a third variable.

The two equations :

$$w = a_1 + b_1 g \quad . \quad . \quad . \quad . \quad (1)$$

and

$$w = a_2 + b_2 q \quad . \quad . \quad . \quad . \quad (2)$$

were then considered in turn, as in the previous papers, and tests, described by Welch (5), carried out to ascertain (i) whether the data fulfilled the conditions required by the later tests of showing similar variabilities in w, after allowing for the relationships implied by the equations, in all treatments, (ii) if so, to see if the treatments affected the values of b_1 or b_2 and (iii) if not, to see if they affected the values of a_1 or a_2.

Material and records

The sets of data available, numbered in sequence with those of the previous papers, were as follows :

*M*4. Thirty bush trees, 41 years old, of Worcester Pearmain on M.II. Originally part of a commercial plantation they formed, for the last fifteen years of their life, two replicates of a manurial trial in five treatments with three trees per plot. The treatments consisted of three different levels of nitrogen, one of phosphate, and an application of both nitrogen and phosphate. The trees were very variable, had very low crotches which in some cases were nearly buried, and over the years, many suffered complete or partial removal of large branches. Thus, while being far from ideal experimental material, they were typical of trees for which some estimate of weight other than that obtained from trunk girth would be needed. *Records.*—Trunk girth midway between union and crotch, this usually being about 9 in. above the union. In some instances this could only be recorded after the tree had been uprooted. Branch girths. Weight of tree above the union.

R8. Eight trees of Allington Pippin, 33 years old, on each of the rootstocks M.I., M.X, M.XII, M.XIII, M.XVI, C and F, together forming a rootstock trial. *Records*.—Trunk girth 9 in. above the union. Branch girths. Weight of the head of the tree. (These trees had been grown as standards and as such were unlikely, in practice, to present much difficulty in the matter of measuring their trunk girths ; for the purpose of this investigation the weights of the trunks were ignored so as to make them more comparable with the type of tree that would present difficulties in trunk measurement.)

U1. Twelve trees of Worcester Pearmain, four years old, on M.VII, planted and grown as part of a uniformity trial intended for such investigations as this. *Records*.—Trunk girth 9 in. above the union. Branch girths. Weight of the head of the tree (as in the case of *R8*, and for the same reasons, the weights of the short 3 ft trunks were ignored).

U2. Twelve trees of Cox's Orange Pippin, four years old, on M.VII, planted and grown as in *U1*. *Records*.—As in *U1*.

U3. Eleven trees of Worcester Pearmain as in *U1* but seven years old. *Records*.—As in *U1*.

U4. Nine trees of Cox's Orange Pippin as in *U2* but seven years old. *Records*.—As in *U1*.

All branch girths were measured as close as possible to the crotch, consistent with avoiding any basal flare or deformity. Where a main branch bifurcated close to its base the sub-branches were measured separately and regarded as main branches.

Results

Correlation coefficients of w with g and q are set out in Table I, together with ν, the number of degrees of freedom for each correlation. Also shown is the value of t (Student's t) for the comparison of r_{wq} with r_{wg}, this having $(\nu - 1)$ degrees of freedom. While Q gives a significantly higher correlation with tree weight than does G ($P < 0{\cdot}05$) for trial *M4*, both variates would appear to be similarly correlated with tree weight as far as the other trials are concerned.

TABLE I

CORRELATIONS OF w WITH g (r_{wg}) AND q (r_{wq}), EACH WITH ν DEGREES OF FREEDOM AND VALUES OF t FOR THE COMPARISON OF r_{wg} WITH r_{wq}

Trial	ν	r_{wg}	r_{wq}	t
M4	24	·959	·984	2·228*
R8	48	·838	·808	·586
U1	10	·806	·772	·247
U2	10	·891	·857	·887
U3	9	·925	·952	·773
U4	7	·987	·982	·546

* = significant at $P < 0{\cdot}05$

Further examination of the data from the two trials involving experimental treatments, *M4* and *R8*, showed the variation in tree weight for a standard value of either G or Q to be unaffected by treatments.

Neither manures nor rootstocks as treatments affected the values of b_1 or b_2 in equations (1) and (2) respectively with the possible exception of an effect of manures on b_1, the regression coefficient of w on g. In this instance there was a significant effect, but the 5 per cent significance level was only just reached and in the light of earlier results, although they did not involve nitrogen treatments (3), too much importance should not be attached to it.

For the manurial trial it was found that neither a_1 nor a_2 were affected by treatments, but for the rootstock trial both a_1 and a_2 differed significantly between treatments ($P < 0{\cdot}05$ and $P < 0{\cdot}001$ respectively)—as was earlier found to be the case (3). Relative tree weights for the different rootstocks in trial *R8*, supposing them all to have the same girth or the same value of Q and assigning a weight of 100 to M.I, are shown in Table II.

Discussion

From these results it would seem that Q gives an estimate of tree weight which is at least as good as that given by trunk girth. While it will sometimes be better than trunk girth as an indication of tree size, *c.f.* the correlation coefficients for trial *M4*, there is a suggestion that it may be less effective

TABLE II

RELATIVE WEIGHTS OF TREE FOR DIFFERENT ROOTSTOCKS WITH STANDARD GIRTH, G, AND STANDARD INTEGRATION OF BRANCH GIRTHS Q, (M.I = 100)

Rootstock	Standard G	Standard Q
M.I	100	100
M.X	111	90
M.XII	139	178
M.XIII	128	69
M.XVI	98	161
C	76	71
F	125	126

in the comparison of rootstocks. Thus, in trial *R8* the estimated weights of trees on different rootstocks for a standard value of Q are more diverse than those for a standard G. These figures are set out in Table II and it is noteworthy that while the rootstock effect using Q is similar to that previously found(3), it is not so when G is used. This is probably the result of the trees concerned being standards and not bush trees as previously studied.

The recommendation to use Q as a means of estimating tree weight in those cases where trunk girth would normally be used but for some reason is not practicable, appears, therefore, to be well founded.

Summary

The recommendation to substitute an integration of branch girth for trunk girth as an estimate of tree size when the measurement of trunk girth is impracticable is examined empirically and found to be satisfactory in any circumstances in which trunk girth would be useful if available.

REFERENCES

(1) BATEN, W. D. (1941.) How to determine which of two variables is better for predicting a third variable. *J. Amer. Soc. Agron.*, **33**, 695-9.

(2) HOTELLING, H. (1940). The selection of variates for use in prediction with some comments on the general problem of nuisance parameters. *Ann. math. Statist.*, **11**, 271-83.

(3) PEARCE, S. C. (1952). Studies in the measurement of apple trees. I. The use of trunk girth to estimate tree size. *Rep. E. Malling. Res. Sta. for 1951*, 101-4.

(4) ——— (1956). Studies in the measurement of apple trees. III. The use of branch girths as a substitute for the trunk girth. *Rep. E. Malling Res. Sta. for 1955*, 76-9.

(5) WELCH, B. L. (1935). Some problems on the analysis of regression among k samples of two variables. *Biometrika*, **27**, 145-60.

THE OCCURRENCE OF AREAS OF POOR GROWTH IN A FRUIT TREE NURSERY

By J. A. THOMPSON

It is common experience with nurserymen that the continued use of the same land for propagating fruit trees may lead to poor growth of rootstocks and young trees. Land that has not previously been used as a nursery is accordingly preferred and when this is not obtainable several years' rotation with other crops is generally employed. As, however, there is little factual information on the persistence of the influence from one nursery crop to another, it is of interest to describe a recent example recorded at East Malling.

In 1958 it was observed that there were bands of poor growth at right angles to the rows of the nursery on Ditton Fields (Fig. 1); the effect was most marked for apples, marked for quinces, cherries, and some plums, but not for myrobalans, currants, or gooseberries. For example, trees of the apple rootstock M.VII were mostly from 45 to 50 in. in height, but in the bands only 20 to 30 in. Quinces were less affected, but were poor in the same bands as the apples, being a little shorter there and considerably less bushy. Cuttings of St. Julien A and cherry rootstocks grew normally in those bands where apples and quinces were poor, but less well elsewhere. Cherry rootstocks, for example, reached only 40 to 50 in. in those bands where growth of apples was good, whereas normal ones were from 60 to 70 in. As all the rootstocks were cut back to 15 in. at the time of planting, the differences in height represent even greater differences in extension growth. Boundaries of the bands were in general sharply defined, but on the west side of the field transitions from normal to poor growth were not always abrupt.

Recent history

Ditton Fields was taken into use as a nursery in 1941 and in that and the following two years planted with stool and layer beds, the east side of the field being planted up first. These were apples (M.I, II, IV, VII, IX, XVI, Crab C), quinces (A, B, C), plums (Myrobalan B, Brompton, Common Plum) and cherries (F12/1, F12/4), the plums and cherries being planted together, in two broad bands along the length of the field. The quinces were planted in rows between the apples and the two together made up the rest of the field, forming three broad bands.

Grubbing began in the winter of 1948-9 on the west side of the field when roughly half of the apples and quinces and almost all of the plums and cherries there were removed. More of the apples and quinces on that side were taken out in the following winter and also in that of 1950-1, when in addition a few rows were taken out from the east side. In the following year more rows of apples were grubbed on that side and the field was cleared in the winter of 1952-3. The whole field was then put into arable cropping for five seasons, during which wheat, seed cocksfoot (3 years) and potatoes were grown.

Discussion

On comparing the plans of the previous and present nurseries (Fig. 2) it is clear that those areas that grew poor crops in 1958 were the ones that had carried related species previously. On the west side of the field, however, growth of cherries following 'stone fruit' was good, and the boundaries of the bands were indistinct. This difference may be due to the fact that the east side of the field had carried stool and layer beds longest. Not only was it planted earlier, but also many of the plums and cherries on the west side were removed as long ago as the winter of 1948-9 whereas the east side was largely intact until four years later. It is interesting that the influence of the previous nursery should have carried through the five seasons of other crops including the three years of heavily manured cocksfoot grass.

As these observations relate to one year's growth only it is difficult at this stage to discuss the bearing they may have on the wider 'replant problem', sometimes referred to as 'Soil Sickness', but it seems at least possible that similar factors may be involved; work on this problem has been summarized by Manaresi (2) and Schander (3, 4). It is interesting also to compare the situation with that shown in a recent investigation into the restoration of land uniformity at East Malling (1), where it was shown that after three years' arable cropping increase in girth of apple rootstocks was only slightly less at old tree positions in the first year of growth.

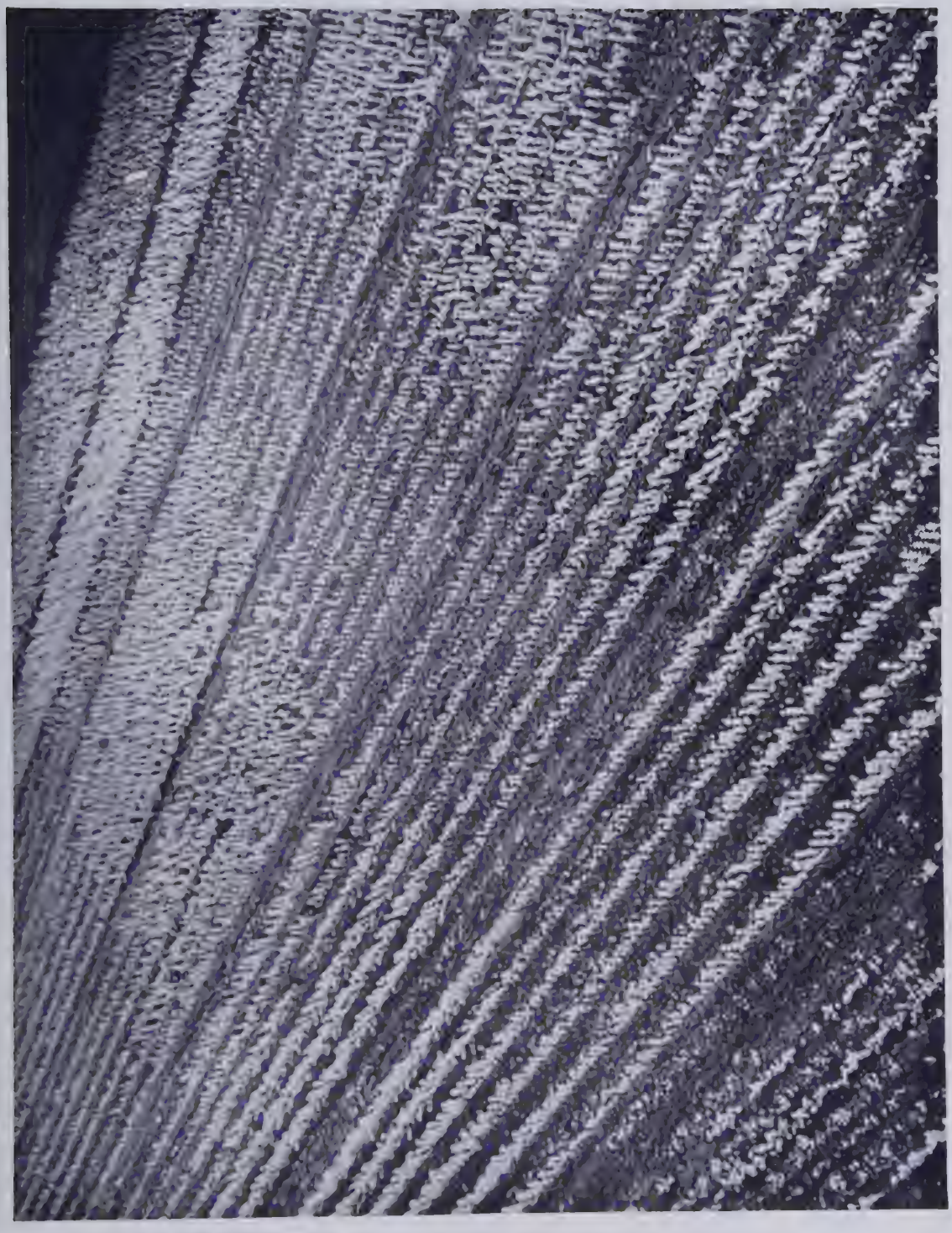
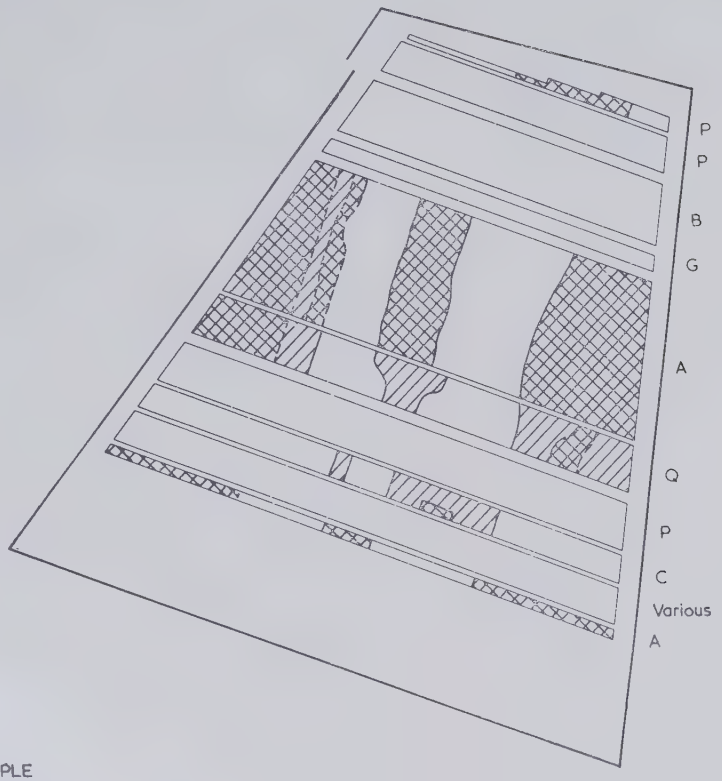


Fig. 1

Apples (and Quinces in the background) showing bands of poor growth. [illegible] of 80 feet.



A APPLE
B BLACKCURRANT
C CHERRY
G GOOSEBERRY
P PLUM
Q QUINCE

NORMAL
POOR
VERY POOR

SHARP BOUNDARY
GRADUAL TRANSITION

FIG. 2a

Plan of nursery in 1958 showing areas of poor growth.

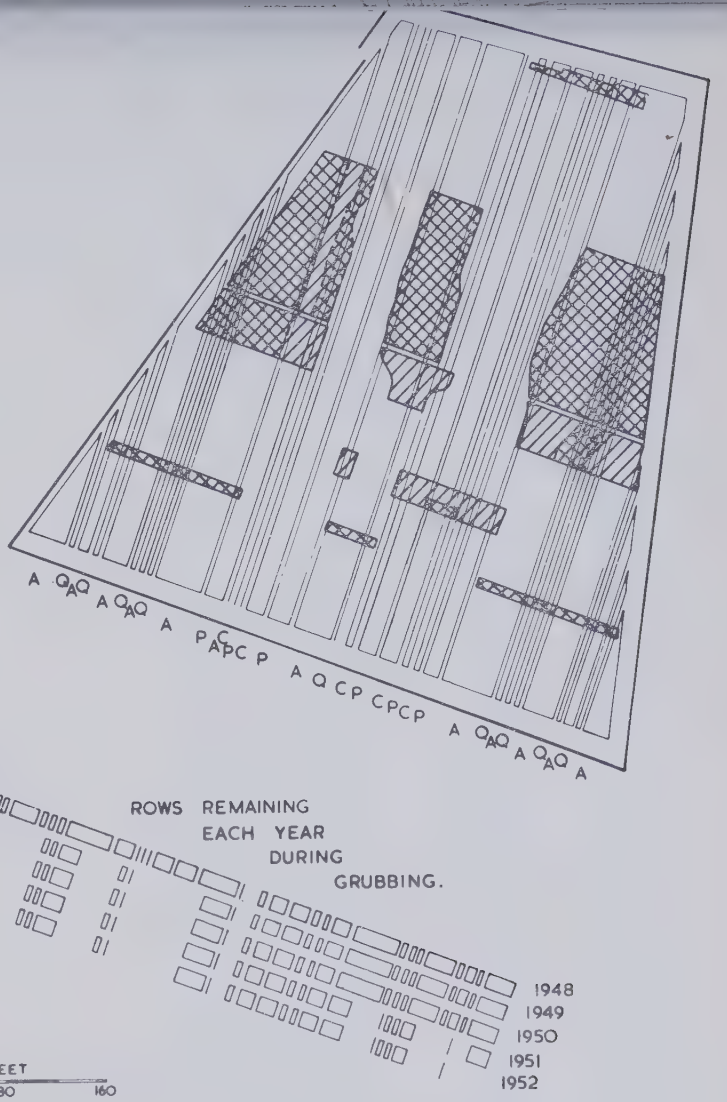


FIG. 2b

Plan of nursery in 1948 with areas of poor growth superimposed, and the progress of grubbing shown below.

Acknowledgements

I am indebted to Mr. H. R. J. Byford, Dr. D. W. P. Greenham and Dr. R. S. Pitcher for their active co-operation and to Mr. E. Y. Jones who, with the help of the Kent County Fire Department took the photograph.

Summary

A description is given of a recent example of the poor growth of nursery material on land previously occupied by related species.

References

(1) Holland, D. A., and Greenham, D. W. P. (1958). The minimization of variability in experiments on apples planted on the site of a previous orchard. I. The effect of cultural treatments associated with three years' arable cropping. *J. hort. Sci.*, **33**, 153-70.

(2) Manaresi, A. (1953). La stanchezza del terreno nei vivai di piante legnose. *Ital. agric.*, **90**, 477-92.

(3) Schander, H. (1955). Beiträge zur Frage der Boden müdigkeit bei Obstgenhölzen. I. *Gartenbauwiss.*, **2**, 115-40.

(4) ——— (1955). Beiträge zur Frage der Boden müdigkeit bei Obstgenhölzen. II. *Gartenbauwiss.*, **2**, 233-60.

PLANT PHYSIOLOGY

THE EFFECT OF THE ORIGINAL SITUATION OF THE SCION ON ITS SUBSEQUENT GROWTH

By D. H. MAGGS

In a recent interpretation (6) of pruning experiments it was assumed that all the buds along a shoot have the same growth potential; in other words they would all grow into shoots of similar size if they were all similarly situated, instead of being distributed from top to bottom of the shoot. The differences in growth that these buds do exhibit when forced into growth by pruning are therefore ascribable to their different situations (such as—farther from the trunk, attached to a thinner piece of stem, etc.) rather than to inherent differences in growth potential. This assumption was only applied to shoots up to three years old. With older shoots of seedling trees, seedling types of shoot would in some cases be produced, though it seems likely that all the buds of a grafted tree would have a similar growth potential. Garner *et al.*(3) have shown that differences in rooting capacity of leaf-bud cuttings associated with their position on the shoot are due to the heel of stem tissue and not to the bud itself.

One method of finding out whether the buds along a shoot have the same growth potential is to graft them individually on to a uniformly pruned rootstock and observe their subsequent growth. This is normal nursery practice, although generally only the middle portion of the graft- or bud-stick is used, since the basal buds are considered to be too weak and the tip ones unripe. A question of such practical importance has naturally been investigated several times. For apples, the results have shown that the site within the tree from which the bud came did not appreciably affect its subsequent growth (1, 2, 7, 8). Crandall's (2) experiments lasted over ten years, and his comparisons included tip and basal buds, buds from watershoots, and terminal buds, all of several varieties; his conclusions were confirmed by Sax and Waltman (7, 8), who were concerned with maiden growth. These American workers used seedling rootstocks, but their results were largely confirmed and amplified by Cannon (1) using clonal rootstocks. He found that the source of bud did not affect the maiden growth of apples, but that with pears slightly larger maidens grew from buds from the upper part of the bud-stick and from young trees, while in one experiment grafted scions (not budded) from the lower part of the shoot grew 6 per cent longer than those from the upper part. Although it seemed fairly certain that there were no differences in growth potential large enough to account for the effects of pruning, in view of the importance of the point to our programme of growth studies, a further experiment was made using carefully selected trees grown in pot-culture, thus ensuring greater uniformity of growth.

Materials and method

Twenty rooted layers of the rootstock M.XVI were selected for uniformity of length and diameter from a large batch, and potted up. The source stoolbed had previously been found to be free from rubbery wood and mosaic viruses. Shortly after bud-break the plants were grafted, half the original length being cut off in the process. Grafting in the dormant season was used in preference to summer budding, in order that the buds might be nearer the condition in which they would normally break in the spring. The scions were obtained from three layered shoots of the same clone; the top 5 cm. and the basal etiolated part were cut off, and the residue divided into five parts, viz. top, upper intermediate, middle, lower intermediate and basal. To reduce scion tissues to a reasonable minimum, two-bud grafts were used, the unwanted portions of the grafts being discarded. Thus 15 trees in all were grafted, giving three replicates of each position. The grafted plants were kept in an unheated greenhouse until summer, when they were 'plunged' outside. Only the best shoot was allowed to develop on each scion, and all leaves were removed from the stocks.

Routine measurements were made of leaf area and shoot extension. Growth was very uniform and when the plants were finally harvested only the scions were weighed, previous work having shown that the rest of the plant would only show parallel differences (6). The plants were harvested on 9th September, when in full leaf, but when little further change in weight would take place.

Results

Development

The ' take ' of the grafts was reasonably good, only three out of the fifteen failing to grow ; of these, two were basal and one was upper-intermediate. Another plant (lower-intermediate) died subsequently through a root infection. Bud-break of the scions was not simultaneous, but there was no evidence of any tip to base gradient. By the time stem elongation began no marked differences remained, though there were significant differences in the total leaf area (Table I A). Fig. 1 shows the plants arranged according to source and treatment on 28th July ; they were re-randomized after being photographed.

Final weight

At harvest leaves and stems were weighed separately ; after drying, fresh weight/dry weight ratios were calculated and any aberrant values checked immediately. Treatment differences in fresh weight were just above the required 1 in 20 level of significance ; in dry weight, they were just below it (Table I B). These differences are largely attributable to early differences in leaf area, as may be seen by comparing the two parts of Table I. The covariance between final weight and leaf area on 28th May is significant, and allowance for this reduced the standard error of the treatment means by over 100 per cent from 2·65 to 1·17 g. dry weight. It may be concluded that had there been full replication of all treatments dry weights would have differed significantly, but that such differences could be ascribed to differences in leaf area existing by the end of May.

Leaf weights closely paralleled total dry weights and will not be discussed.

TABLE I

LEAF AREAS AND FINAL DRY WEIGHTS

	A Total leaf area (sq. cm.) 28.v.57					B Total dry weight of scion (g.) 9.ix.57				
Position	1	2	3	4	5	1	2	3	4	5
Graft-stick										
I	116	83	156	77	—	28·3	28·7	33·5	24·4	—
II	115	54	141	110	96	27·2	21·0	33·0	28·3	29·8
III	128	—	132	—	—	28·3	—	32·9	—	—
Average	120	69	143	93	96	27·9	24·8	33·1	26·4	29·8
Least sig. diff. (3 replicates)			30					5·0		

Discussion

The object of this experiment was to find out whether any inherent difference in growth potential between buds could account quantitatively for the pruning response. For this to be so, the scions from the basal part of the graft stick would have had to have made two to four times the growth of those from the upper part, and as will be seen from Table I, this has not in fact occurred. It may therefore be concluded that variation in growth potential between the buds themselves is not an important factor in the response of the tree to pruning. Nevertheless, there were differences in the growth made by scions from different parts of the shoot, and these differences could be traced back to differences in total leaf area at a time when stem elongation itself had scarcely begun. Similar dependence of end-of-season growth on beginning-of-season growth and on date of bud-break has already been reported (1, 5, 6), and it seems probable, therefore, that the factors which determine the time of starting and stopping of growth will prove to be of importance in an analysis of the total growth of the fruit tree. The relative importance of the actual differences which are associated with variations in bud position remains doubtful. The individual buds may indeed have different growth potentials depending on the circumstances prevailing at the time of their initiation and development ; but the distribution of these growth potentials appears to be irregular, just as there is no apparent pattern in the distribution of the flower buds along the shoot (4).

Summary

Two-bud grafts taken from five positions along the graft-stick were worked on to selected root-stocks grown in pots to determine differences in growth due to position on the graft-stick.

Fig. 1

Experimental trees on 28th July arranged according to treatments. Trees at left from the upper part of graft stick and on right from the lower part.

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The differences in growth between treatments were not as great as those which would be expected if the buds had been stimulated by pruning.

The differences in weight between treatments could be accounted for by differences in leaf area as early as 28th May.

References

(1) Cannon, H. B. (1941). Studies in the variation of nursery fruit trees on vegetatively raised rootstocks. *J. Pomol.*, **19**, 2-33.

(2) Crandall, C. S. (1918). Apple bud selection. Apple seedlings from selected trees. *Bull. Univ. Ill. Agric. Exp. Sta.*, **211**.

(3) Garner, R. J., Hatcher, E. S. J., and Nicoll, C. P. (1954). Experiments with apple leaf-bud cuttings. *Rep. E. Malling Res. Sta. for 1953*, 145-9.

(4) Maggs, D. H. (1955). The inception of flowering in some apple rootstock varieties. *J. hort. Sci.*, **30**, 234-41.

(5) ——— (1958). A comparison of the growth patterns of two apple rootstock varieties during their first year. *Rep. E. Malling Res. Sta. for 1957*, 101-5.

(6) ——— (1959). The pruning response of one-year apple trees. *Ann. Bot., Lond.* (In press).

(7) Sax, K. (1923). Bud and root selection in the propagation of the apple. *Proc. Amer. Soc. hort. Sci.*, **20**, 244-56.

(8) Waltman, C. S. (1938). The first season's growth of apple grafts as affected by type of stock and part of scion. *Circ. Ky. Agric. Exp. Sta.*, **49**.

PLANT ANALYSIS

A PROGRESS REPORT ON THE MINERAL COMPOSITION OF LEAVES FROM SELECTED APPLE ORCHARDS IN THE EASTERN COUNTIES OF ENGLAND

By A. C. MASON and A. B. WHITFIELD

Thirty-two commercial apple orchards were visited in July 1957 for the purpose of collecting samples of leaves for chemical analysis, and it is proposed to repeat the survey annually for 2 or 3 years. Although surveys of this kind have been carried out in other countries there appears to be no comparable information on the leaf composition of apples of specified variety and rootstock grown by progressive farmers in Britain. The aim was to determine the levels and degree of variation for the major elements in the leaves and to compare these values with those available for other countries ; also it was hoped to establish whether leaf composition was correlated with the yield and the keeping quality of the fruit, an aspect which will be dealt with elsewhere.

At this stage it was considered desirable to restrict attention to one variety and rootstock, and orchards of trees approximately 20 years old of Cox's Orange Pippin on M.II rootstock were selected for relatively high or low yields and relatively good or bad keeping quality of fruit. By selecting orchards from several counties a good range of climate, soil type and cultural practice was covered though no attempt has been made to relate these factors to leaf analysis. On some sites damage to the foliage by wind and hail had been severe, also in many orchards attacks of mildew were serious which made it difficult to obtain satisfactory samples of leaves.

Sampling procedure

At each orchard the grower had allocated four trees which were sometimes grouped together and sometimes scattered. Each tree was labelled with a serial number and three persons selected three different types of leaf sample as follows, each person taking one type of sample throughout :

F type.—The youngest fully grown leaves on extension and lateral shoots were taken from the periphery of the tree up to a height of about 8 ft.

M type.—The middle leaves from similar shoots.

R type.—The largest leaf in a rosette of leaves from a non-fruiting spur.

Sixteen leaves of each type were taken from each tree and every sample was kept separate. The leaves were placed in calico sample bags which were gathered together and stored in larger polythene bags to restrict loss of moisture. According to the location of the orchard, samples were stored thus for periods varying from 3 to 48 hours. On receipt at the laboratory the samples were washed (3) and the petioles and midribs removed. The samples were then dried at 80°C. and ground in a Christy and Norris mill for analysis.

Standard routine microchemical methods were used to determine nitrogen, phosphorus, potassium, calcium, and magnesium all of which are subject to a standard error of less than 3 per cent of the determined value. All results are expressed as percentages of the element in oven dried leaves.

Discussion

Three different types of leaf sample were selected because it is evident from other unpublished work that the results of analysis from a single leaf type sampled on one occasion can sometimes be misleading. It would have been preferable to sample on two occasions, say July and September, but this was not possible. The youngest fully grown (F type) leaf was chosen because it is probably making the greatest demands for nutrients; the mid-shoot leaf (M type) is widely used in England and abroad for leaf analysis; the largest rosette leaf from a non-fruiting spur (R type) is likely to be physiologically different from the other leaf types and it has the advantage that such leaves can always be found even when, due to lack of extension growth, the other types of leaf are not available. It was, of course, necessary to choose leaf types which could be recognized easily and with precision, in order to minimize errors in selecting the leaves.

In one orchard the rootstock was subsequently discovered to be M.I and results for this orchard are therefore omitted and the number of orchards was reduced to thirty-one.

Table I

Leaf analysis survey of 31 orchards in Kent, Essex and East Anglia on 15th-20th July, 1957
concentrations expressed as percentage of dry matter

Element		N			P			K			Ca			Mg		
Type of leaf		F	M	R	F	M	R	F	M	R	F	M	R	F	M	R
9 Cultivated orchards	Lowest	2·41	2·78	2·65	0·23	0·19	0·20	1·30	1·18	1·12	0·50	0·67	1·09	0·23	0·18	0·21
	Highest	3·19	3·08	2·92	0·27	0·24	0·26	1·84	1·72	1·63	0·86	1·09	1·61	0·31	0·29	0·34
	Mean	2·89	2·92	2·78	0·25	0·22	0·22	1·49	1·48	1·36	0·70	0·86	1·41	0·26	0·25	0·29
22 Grass orchards	Lowest	2·15	2·30	2·22	0·21	0·20	0·19	0·91	0·92	0·85	0·55	0·61	1·02	0·22	0·18	0·23
	Highest	3·22	3·15	2·99	0·34	0·28	0·26	1·61	1·79	1·57	1·06	1·20	1·79	0·35	0·31	0·36
	Mean	2·53	2·70	2·61	0·25	0·24	0·22	1·32	1·37	1·23	0·75	0·90	1·40	0·28	0·24	0·29
General Mean for 31 orchards		2·63	2·77	2·66	0·25	0·23	0·22	1·37	1·40	1·27	0·74	0·89	1·40	0·27	0·24	0·29

Table II

Summary of the results of some apple leaf analysis surveys

Locality	Variety	Remarks	N%	P%	K%	Ca%	Mg%
1957 England	Cox/M.II	20 years old. Sampled 15th-20th July. M. type leaves. Mean of 31 orchards (124 trees).	2·77	0·23	1·40	0·89	0·24
1957 East Malling	Cox/M.II	13 years old. Sampled 24th July. Cultivation M type leaves. Mean of 4 trees.	3·07	0·25	1·27	0·93	0·21
1957 East Malling	Jonathan/M.II	Mean of 4 trees. M type leaves.	2·69	0·22	1·04	0·95	0·20
1955 Japan, Aomori	Jonathan	Sampled 25th July-5th August (Shibukawa *et al.* 1956)					
		Mean of 579 samples	3·16	0·17	1·45	——	——
		Lowest	2·60	0·11	0·86	——	——
		Highest	4·06	0·27	2·18	——	——
1957 Japan, Aomori	Jonathan	Sampled 25th July-5th August (Shibukawa *et al.* 1957)					
		Mean of 634 samples	3·37	0·18	1·26	——	——
		Lowest	2·64	0·12,,	0·63	——	——
		Highest	4·20	0·38	2·04	—	——
1950 U.S.A. Michigan	Jonathan	Sampled 15th July-15th August (Kenworthy, 1950)					
		Mean of 13 samples	2·45	0·23	1·65	1·58	0·44
		Lowest	2·09	0·09	0·60	0·90	0·29
		Highest	2·79	0·54	2·82	2·67	0·62

A summary of the results of analysis of the samples of leaves is presented in Table I. Values obtained for 9 orchards under cultivation are contrasted with those for 22 orchards under permanent grass cover. The mean nitrogen content of the leaves of each type F, M, and R are higher under cultivation than under grass, also the values for potassium are slightly higher. The greater range of values for orchards under grass cover is probably due to the larger number sampled, since there is no reason to suppose any real difference in variability. Unfortunately it is not possible to make a strict comparison between these data and data available from foreign orchards as Cox has not been widely grown abroad. There is a certain amount of survey data available from abroad for the variety Jonathan and comparisons can be made after allowing for the effect of variety on leaf composition ; a tentative estimate of this effect has been made on the basis of a few trees of Cox and Jonathan grown in the same orchard at East Malling. The available data, summarized in Table II, suggest that, after allowing for the lower content of nitrogen in the leaves of Jonathan, apple trees grown commercially in England bear leaves with a similar content of nitrogen and phosphorus to those grown in Michigan, U.S.A., but with a decidedly lower content of calcium and magnesium. The figures for this one season also suggest that in England leaves contain less potassium than in the U.S.A. or Japan.

With regard to the variety Jonathan, East Malling figures for potassium are considerably lower than those reported for Japan and for Michigan U.S.A. while the figures for nitrogen in the leaves of East Malling trees fall between those reported for Japan and for Michigan, U.S.A. There are very big differences in magnesium for Jonathan grown at East Malling and in Michigan (0·20 compared with 0·44 per cent), but unfortunately there are no values reported from Japan.

With regard to Cox grown in commercial orchards in England and those grown at East Malling, there are only small differences in content of phosphorus, calcium and magnesium but the commercial orchards have, on the average, a higher concentration of potassium and a lower concentration of nitrogen in the leaves.

The figures which are discussed above are for two specific varieties of apple but it is interesting to compare them with the following mean values obtained by Emmert (1) from 13 separate leaf analysis surveys considered together without regard to variety, rootstock, sampling time, etc.

N	P	K	Ca	Mg
2·16	0·22	1·45	1·27	0·30

It is again emphasized that the results reported in this paper are interim and conclusions should not be drawn until data are available for several years. The variation which can occur from one year to the next is illustrated by the results given in Table II for 1955 and 1956 in the Japanese orchards.

Acknowledgements

We wish to record our appreciation of the kindness and co-operative spirit of the many growers and their staffs in freely granting us sampling facilities in their orchards and for their help in answering questions. The survey is being carried out in collaboration with the team working on fruit storage and we express our thanks to Dr. H. B. S. Montgomery and Dr. M. P. Denne who made arrangements for the tour and helped in collecting the samples. The chemical analyses were carried out by members of the staff of the Plant Analysis Section.

Summary

Samples of three different leaf types were collected from 9 cultivated and 22 grass orchards in mid-July 1957. These have been analysed for content of nitrogen, phosphorus, potassium, calcium and magnesium, and the results summarized and compared with the mean values obtained in other foliar analysis surveys.

References

(1) Emmert, F. H. (1955). Foliar analysis results from forty Connecticut apple orchards. *Bull. Storrs Agric. Exp. Sta. Conn. U.S.A.*, **317.**

(2) Kenworthy, A. L. (1950). Nutrient element composition of leaves from fruit trees. *Proc. Amer. Soc. hort. Sci.*, **55,** 51-6.

(3) Mason, A. C. (1953). The cleaning of leaves prior to analysis. *Rep. E. Malling Res. Sta. for 1952*, 104-7.

(4) Shibukawa, J., Nagai, K., Soma, M., Ono, T., Ichiki, S., Izumiya, A., Uno, T., Yamada, S., Sato., K., and Tsubota, S. (1957). Studies on leaf analysis of apple trees. I. A leaf analysis survey of apple orchards. *Misc. Pub. Aomori Apple Exp. Sta., Aomori, Japan*, No. 9.

(5) Shibukawa, J., Nagai, K., Soma, M., Yamashita, K., Izumiya, A., Uno, T., Yamada, S., and Nakamura, M. (1956). Studies on leaf analysis of apple trees. I. A leaf analysis survey of apple orchards. *Misc. Pub. Aomori Apple Exp. Sta., Aomori, Japan*, No. 8.

PLANT PATHOLOGY

THE REDUCTION IN YIELD CAUSED BY APPLE MOSAIC

By A. F. POSNETTE and R. CROPLEY

A field trial to measure the effect of apple mosaic virus on the yield of four varieties was described in 1956 (1). This trial was continued and an account is now given of the performance of the trees over a six-year period.

Materials

When inoculated (by grafting) with two strains of the virus in 1950-1, the trees of Allington Pippin, Cox's Orange Pippin, Newton Wonder and Worcester Pearmain on M.IX stocks were 23 years old. These mature trees were used to avoid the usual effect of mosaic in reducing tree size when infected scionwood is used for propagation (1). Nine trees of each variety were infected with each strain of the virus and nine left uninoculated as controls. Four infected scions were grafted onto each tree and mosaic symptoms had become widely distributed over the Allington and Cox trees by 1952 and the Worcester trees by 1953. Symptoms were localized near the inoculation sites on the Newton Wonder trees, and tests in 1954 showed that the virus had not then moved from the inoculated branches. Although randomized among the infected trees, none of the controls showed any sign of infection throughout the trial.

Results

The yields of the three groups (mild strain-infected, virulent strain-infected and controls) are shown in the graphs, excepting those of the Newton Wonder trees in which any virus effects were vitiated by extreme biennial bearing with the infected and the control trees cropping heavily in different years.

The effect of apple mosaic virus in reducing the crop was proportional to the severity of mosaic symptoms, which developed on most of the leaves on Allington trees infected with the virulent strain whereas comparable Cox and Worcester trees showed symptoms mostly on spur leaves and the basal leaves of extension shoots. The mild strain produced slight mosaic on Allington leaves but only inconspicuous flecks on Cox and Worcester and no symptoms on Newton Wonder.

The first indication of a depression in yield occurred in the Allington trees in 1952, two years after inoculation. The maximum depression (40 per cent) occurred in 1954 with both Allington and Cox, in 1955 with Worcester (30 per cent). No further decline occurred after these years and the trial was terminated in 1957, a year in which the crop was destroyed by spring frost.

The mild strain of the virus slightly reduced the crop of Allingtons (the reduction being statistically significant in 1955-6 but not in 1953-4). In Cox, however, the effect was as severe as that of the virulent strain, and this provides a clear example of the losses that latent virus infection can inflict on the fruitgrower without his knowledge.

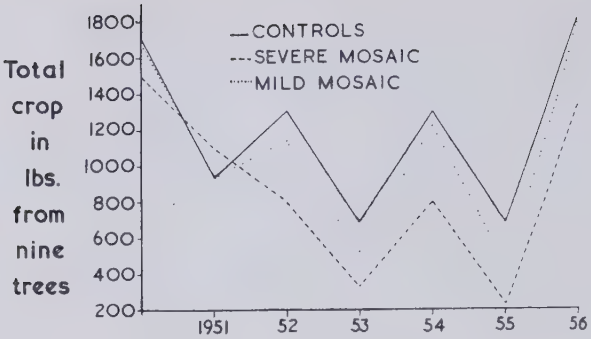
Statistical analysis

The crop weights for 1953-4 and 1955-6 were analysed separately, each corrected for the tree's girth in 1950 and crop in 1950-1. The corrected mean yields are given in the Table.

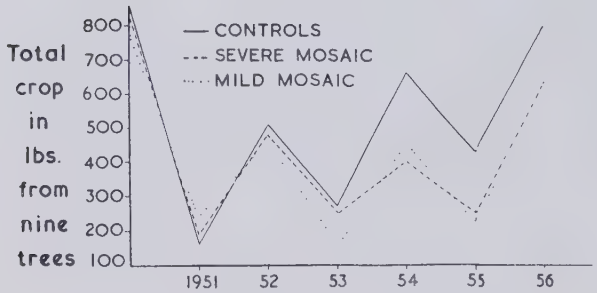
Although the Worcester trees infected with the virulent strain yielded less fruit than the control trees in 1953, 1955, and 1956, they were too variable for the differences to be statistically significant.

MEAN CROP IN LB. PER TREE CORRECTED BY COVARIANCE ON PREVIOUS GIRTH AND CROP IN 1950-1

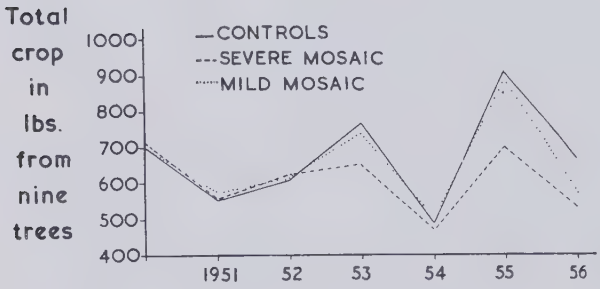
Variety	Crop years	Virulent mosaic	Mild mosaic	Control	Min. sig. diff, (P=0·05)
Allington ..	1953–4	101·1	165·2	183·7	27·4
Allington ..	1955–6	148·0	210·4	252·7	27·9
Cox	1953–4	62·2	60·7	94·0	27·5
Cox	1955–6	93·7	84·6	120·6	33·8



ALLINGTON PIPPIN CROPS



COX'S ORANGE PIPPIN CROPS



WORCESTER PEARMAIN CROPS

Summary

In a field trial continued for 6 years with four varieties of apple, two strains of the apple mosaic virus reduced the yield of mature Cox's Orange Pippin and Allington Pippin trees by about 30 per cent over a period of 4 years. The yield of Worcester Pearmain and Newton Wonder trees was only slightly reduced. Particular interest arises from the effect of the mild strain which causes inconspicuous or no symptoms in most apple varieties.

Reference

(1) Posnette, A. F., and Cropley, R. (1956). Apple mosaic viruses : host reactions and strain interference. *J. hort. Sci.*, **31**, 119-133.

A SELECTION OF WILLIAMS' BON CHRÉTIEN PEAR COMPATIBLE WITH QUINCE ROOTSTOCKS

By A. F. POSNETTE and R. CROPLEY

Incompatibility, or uncongeniability, between some varieties of pear and quince rootstocks is well-known to horticulturists. Its possible causes have been investigated by numerous workers (e.g. Mosse and Scaramuzzi (5)), and the practice of double-grafting or double budding with a compatible interstock has proved a satisfactory means of propagating trees with strong unions (2, 3). The possibility of virus infection causing this incompatibility, as with some stock-scion failures in citrus and apple (8), could not be investigated until a compatible combination of the scion and stock varieties concerned was available for inoculation with incompatible material. An experiment with compatible and incompatible combinations of Williams' Bon Chrétien on clonal Quince A rootstocks is described below.

Materials

Three ' strains ' of Williams' were used : (a) an English clone which had consistently shown incompatibility with quince over a period of many years (1) ; (b) a French clone introduced to East Malling Research Station in 1945 with a reputation for compatibility ; (c) a Swiss clone obtained from a nurseryman near Zurich who vouched for its compatibility with quince stocks.

Tests by budding to quince indicator plants revealed no latent viruses in the English or French clones, but the Swiss material was infected with vein yellows and bark necrosis viruses (6).

In 1954, four sets of trees were propagated by budding on clonal Quince A stocks :

1.	English clone :	8 trees.
2.	French clone :	10 trees.
3.	French clone with a bud of the English clone 2 in. lower on each stock :	7 trees
4.	Swiss clone :	15 trees.

Results

In the winter of 1956-7, when the scions had grown for two years, three trees of each group were lifted and their unions examined. The trees of the English clone showed obvious signs of incompatibility in bark and wood, while the trees of the Swiss clone had strong unions with vascular continuity comparable with that in compatible combinations such as Beurré Hardy on Quince A (Fig. 1). The French clone trees had strong unions, although showing some areas of discontinuity in the wood and slight infolding of the bark. The trees of the French clone with the additional bud of the English were indistinguishable at their unions from the uninoculated trees.

The remaining trees were grown until the autumn of 1958, by which time only one of the English trees was still intact, the remainder having snapped off with a clean break at the union. The unions of the French and Swiss trees remained strong, the latter having smooth unions and the former showing only slight signs of incompatibility : a thin line of necrosis in the outer bark and a bulge above the union greater that that on the Swiss trees but markedly less than on the English ones. No effect of the inoculation could be seen ; the union between the English scions and the Quince A stocks snapped off readily (Fig. 2), but the presence of this incompatible scion on the same stock had not affected the union with the French scions (Figs. 3 and 4). The great variability in trees of the same stock-scion combination reported by Mosse (4) was not apparent in this experiment.

Discussion

The way in which these results are interpreted depends on the identification of the scion clones. Careful examination of vegetative and fruit characters has revealed no distinguishing characters and there seems no reason to doubt that all three clones are true Williams', unless incompatibility with quince stocks is regarded as a characteristic feature of the variety. This investigation suggests that incompatibility between pear and quince is not due to a graft-transmissible virus, although the possibility remains that it might require longer than four years to affect the unions ; or alternatively the hypothetical virus may not be translocated through Quince A tissue and the incompatible union may be the result of a hypersensitive reaction by the stock to a virus carried in the scion. This is now being investigated, but evidence from an analogous condition known as bud-union crease in

citrus does not support the virus hypothesis (7). It seems more probable that the differences between the clones of Williams' in their compatibility with quince arose originally through bud mutation, presumably but not certainly from incompatible to compatible. Mutations in the reverse direction, from compatible to incompatible, would be expected also and would account for the incompatible form of Conference pear (a variety normally compatible with quince) reported by Williams and Campbell (9).

Acknowledgements

The help and advice given by Dr. Barbara Mosse are gratefully acknowledged.

Summary

Trees of Williams' Bon Chrétien on Quince A rootstocks were propagated from three scion sources, English, French and Swiss. The structure of the graft unions differed, the English source being highly incompatible, the French slightly incompatible and the Swiss compatible.

Both compatible and incompatible unions were formed by different scions of Williams' grown on the same stock for four years. This evidence that the cause of incompatibility is not graft-transmissible suggests that bud mutation, rather than virus infection, is responsible for the differences between clones of the same variety.

References

(1) Garner, R. J. (1948). The nursery behaviour of the Williams' Bon Chrétien pear when worked upon a wide range of quince rootstocks. *Rep. E. Malling Res. Sta. for 1947*, 65-70.
(2) – ——— (1953.) Double working pears at budding time. *Rep. E. Malling Res. Sta. for 1952*, 174-5.
(3) ———, and Hammond, D. H. (1940). Studies in nursery technique. The production of double-worked pear trees. *Rep. E. Malling Res. Sta. for 1939*, 84-6.
(4) Mosse, Barbara (1958). Further observations on growth and union structure of double-grafted pear on quince. *J. hort. Sci.*, **33**, 186-93.
(5) ———, and Scaramuzzi, F. (1956). Observations on the nature and development of structural defects in the unions between pear and quince. *J. hort. Sci.*, **31**, 47-54.
(6) Posnette, A. F. (1957). Virus diseases of pears in England. *J. hort. Sci.*, **32**, 53-61.
(7) Olson, E. O. (1958). Bud-union crease, a citrus disorder associated with some Kumquat-hybrid rootstocks and scions. *J. Rio Grande Val. hort. Soc.*, **12**, 27-34.
(8) Weeks, W. D. (1948). Further scion and stock combinations with Spy 227. *Proc. Amer. Soc. hort. Sci.*, **52**, 137-40.
(9) Williams, R. R., and Campbell, A. I. (1956). Rosetting and incompatibility of pears on Quince A : Progress report I. *Ann. Rep. Long Ashton Res. Sta.*, 51-6.

Fig. 1

Two-year-old unions between Williams' Bon Chrétien pear and Quince A. *Above:* Swiss strain of Williams'. *Below:* English strain

Fig. 2

Williams' Bon Chrétien pear on Quince A. Incompatible union with English strain below strong union with French strain of Williams' (4 years old)

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FIG. 3

Unions of three strains of Williams' pear on Quince A: *left*, Swiss *centre*, French *right*, English (4 years old)

FIG. 4

Unions of three strains of Williams' pear on Quince A: *left*, Swiss; *centre*, French with scar of English scion (same plant as shown in Fig. 2); *right*, English (4 years old)

THE EFFECTS OF COTTON SEED OIL ON THE CONTROL OF BACTERIAL CANKER OF CHERRY WITH AN EARLY AUTUMN SPRAY SCHEDULE OF BORDEAUX MIXTURE

By J. E. CROSSE and MARGERY BENNETT

In a previous investigation there was evidence that infection of cherry leaf scars by *Pseudomonas mors-prunorum* Wormald began the first week of September or earlier (1). This suggested that the timing of the first spray applications, hitherto recommended for late September, might profitably be advanced. When this idea was tested experimentally, two Bordeaux mixture sprays applied in early September (2-3-100) and early October (4-6-100) reduced the amount of disease on the susceptible variety Napoleon by approximately 85 per cent (2, 5). This level of control was higher than any previously achieved, and was attributed primarily to the time of spraying. Both sprays, however, had included cotton seed oil (0·75 per cent v/v) to reduce the risk of premature defoliation, and the question arose as to how far this may have contributed towards the results obtained. Montgomery and Moore(4) originally used cotton seed oil in the control of this disease to prevent damage to the foliage from spring sprays of Bordeaux mixture, but it had not previously been incorporated in autumn sprays.

The experiment described below was designed to test further the effectiveness of an early autumn schedule and find whether the degree of control was influenced by the inclusion of cotton seed oil.

Materials and methods

Experimental design

The trial was conducted in autumn 1957 on 48 four-year-old trees of the variety Napoleon, high worked on F12/1 rootstocks and planted in randomized blocks giving twelve replicated single-tree plots for each of four treatments.

These were as follows :

1. Bordeaux mixture ;
2. Bordeaux mixture + cotton seed oil ;
3. Cotton seed oil (in water) ;
4. Nil.

Three successive sprays were applied in each of treatments 1 to 3, on 19th August, 18th September and 15th October, using 2-3-100, 4-6-100 and 10-15-100 Bordeaux mixture respectively. Cotton seed oil was used at 0·75 per cent v/v throughout. Spraying was done at high volume using a lance to ensure good cover. Trees of the variety Early Rivers, interplanted in alternate rows with the Napoleons, served as screens against drift. The whole plot had received routine farm sprays since planting, the last spray prior to this experiment being 10-15-100 Bordeaux mixture in autumn 1956.

Records

The progress of defoliation was followed by inspecting the trees periodically during the autumn, and allotting to each a category value of 0-15 corresponding to a range of defoliation of 0-100 per cent. Disease incidence was assessed the following spring by the methods described by Crosse and Bennett (3). A count was made of the total number of infections on each tree, and these were then separated into three groups according to the original mode of infection, viz.(a) through wounds and crotches, (b) through leaf scars on fruiting spurs (spur infections), and (c) through leaf scars at the nodes on the one-year-old wood (nodal infections). In groups (b) and (c) a distinction was also made between infections which had spread into the branch (cankers) and those which had not. Treatment effects were compared by an analysis of variance using a log $(n + \frac{3}{8})$ transformation.

Results

Defoliation

The progress of leaf fall under various treatments and the distribution of rainfall during the autumn is illustrated in the diagram (overleaf).

Without cotton seed oil the Bordeaux mixture sprays advanced leaf fall by 2-3 weeks compared with the other treatments, reaching 60-70 per cent by 14th October. Where cotton seed oil was

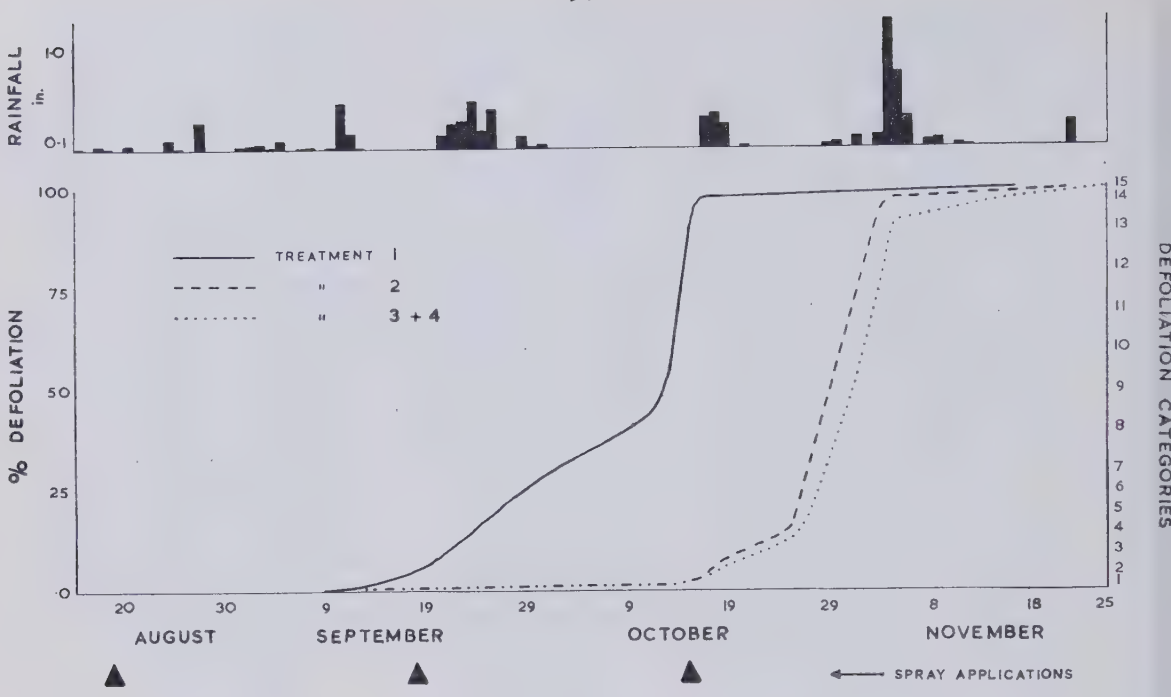

FIG. 1

Progress of leaf-fall in relation to spray treatment and distribution of rainfall

included in the Bordeaux mixture sprays, no defoliant effects were observed until after the third spray on 15th October when leaf fall was advanced by about two days compared with the other treatments. Cotton seed oil alone has no effect on the rate of defoliation.

Disease incidence

The effects of the treatments are summarized below. This shows the total numbers of spur and nodal infections, and the number of these giving rise to branch cankers, as arithmetic means per tree. There was only a single wound infection on the whole plot, on an unsprayed tree.

EFFECTS OF BORDEAUX MIXTURES (B.M.) AND COTTON SEED OIL (C.S.O.) SPRAYS ON SPUR AND NODAL INFECTIONS OF THE CHERRY VARIETY NAPOLEON (MEANS/TREE)

Treatment		Bordeaux mixture			No Bordeaux mixture		
		1 B.M.	2 B.M. and C.S.O.	1 and 2 combined	3 C.S.O.	4 Nil	3 and 4 combined
All infections	Spurs	1·9	1·0	1·4***	16·9	15·3	16·1
	Nodes	1·4	1·0	1·2***	10·8	12·2	11·5
	Total	3·3	2·0	2·7***	27·8	27·5	27·5
Cankers	Spurs	0·3	0·4	0·4***	2·7	5·6	4·1
	Nodes	0·3	0·4	0·4***	3·6	4·6	4·1
	Total	0·7	0·8	0·8***	6·3	10·2	8·2

*** Significantly lower than treatments 3 and 4 combined, at the 0·001 level.

Considering first all infections, it is clear that only Bordeaux mixture (treatments 1 and 2) had an effect. The same is true of cankers, except that there was a slight suggestion that cotton seed o alone (treatment 3) may have reduced spur cankers compared with the unsprayed control, th difference between these two treatments just failing to reach significance at the 0·05 level.

Discussion

It will be clear from the diagram that when cotton seed oil was included in Bordeaux mixture it completely altered the relationship between leaf fall and the distribution of infective conditions, i.e. rainfall. If this had any effect on the disease it was not detected in this experiment, and it was obvious that the Bordeaux mixture was the major factor in control. It should be noted that no sprays were used on the experimental plot in the spring of 1957, so that the control obtained was due to the three autumn applications. The overall reduction in the disease brought about by these Bordeaux mixture sprays was in excess of 90 per cent. This high level of control was reflected in other ways. For example, of the 24 trees under treatments 1 and 2, none showed any signs of die-back, four were totally free of all visible infection, and 14 were free of cankers. By comparison there were seven instances of branch die-back involving five of the 24 trees under treatments 3 and 4. None of these trees was free of infection and only one was free of cankers.

The results of this experiment confirm the conclusions drawn from the previous trial (2) and they suggest that earlier applications of Bordeaux mixture should give good commercial control of the disease *provided* always that effective coverage of the foliage is obtained. Although cotton seed oil apparently contributed little towards disease control, its use seems advisable, pending further information on the long term effects of premature defoliation on the growth of the tree.

Acknowledgements

We are grateful to Miss H. P. Insley and Miss E. J. Basker for their help in conducting this experiment.

Summary

Three applications of Bordeaux mixture applied on 19th August (2-3-100), 18th September (4-6-100), and 15th October (10-15-100) reduced the incidence of bacterial canker infections on cherry by more than 90 per cent. Cotton seed oil prevented rapid defoliation by these sprays, but had no apparent effect on the disease, either separately or in combination with Bordeaux mixture.

References

(1) Crosse, J. E. (1957a). Bacterial canker of stone-fruits. III. Inoculum concentration and time of inoculation in relation to leaf-scar infection of cherry. *Ann. appl. Biol.*, **45**, 19-35.

(2) ——— (1957b). Streptomycin in the control of bacterial canker of cherry. *Ann. appl. Biol.*, **45**, 226-28.

(3) —— and Bennett, M. (1957). Preliminary field trials with streptomycin for the control of bacterial canker of cherry. *Plant Path.*, **6**, 31-5.

(4) Montgomery, H. B. S., and Moore, M. H. (1945). The control of bacterial canker and leaf-spot in sweet cherry. *J. Pomol.*, **21**, 155-63.

(5) Moore, M. H., Crosse, J. E., and Bennett, M. (1959). Spray experiments for the control of bacterial canker of cherry. *Rep. E. Malling Res. Sta. for 1958*, 96-102.

SPRAY EXPERIMENTS ON THE CONTROL OF BACTERIAL CANKER OF CHERRY*

By M. H. MOORE, J. E. CROSSE, and MARGERY BENNETT

Bacterial Canker, caused by *Pseudomonas mors-prunorum*, was originally investigated by Wormald (1937), and shown to have a distinct seasonal cycle, with a summer leaf-spot phase alternating with a winter canker stage in the stems and branches. Control measures devised by Montgomery and Moore (7) were aimed at breaking this cycle with Bordeaux mixture sprays applied in the autumn and spring, when, for short periods, the two phases of the disease overlap. Spraying in the autumn was designed to protect leaf scars and so to prevent the formation of cankers, and in the spring to prevent infection of young foliage. Over a period of several years the sprays reduced the incidence of the disease on the susceptible variety Bigarreau de Schrecken, but did not entirely eliminate it. These experiments led to the recommendation of a basic spray schedule of freshly-made Bordeaux mixture (1 per cent) in mid-October, followed by a second spray (0·6 per cent) in the following spring, at white-bud. A further spray at petal-fall improved canker control in some circumstances, but to avoid leaf scorch the incorporation of cotton-seed oil was necessary at this stage. The position was summarized (9) in a general account of existing control measures.

Investigations since these early experiments have been concerned with two main issues :

1. The evaluation of bactericides, including the antibiotic streptomycin.
2. The improvement of disease control by alterations in the time of spraying.

The results of several of these later trials are summarized in this paper, with particular reference to measures aimed specifically at the control of autumnal canker infections. The use of spring sprays is mentioned where relevant to this problem, but the direct effect of these sprays on the leaf-spot phase of the disease is not discussed here.

General methods

With one exception, described later, the investigations were conducted on one or other of two experimental plots, E23 and C5, both incorporating a randomized block design. Plot E23 consisted of a single variety, Schrecken, planted in 1943 at 20 ft intervals in four blocks, each of eight four-tree plots. Plot C5 comprised the varieties Napoleon and Roundel, planted in 1953 at 8ft in 12 blocks, each of three single-tree plots for each variety. The trees were all low-worked on F12/1 clonal rootstocks.

Unless otherwise stated, sprays were applied at high volume to run-off, using a lance to ensure effective coverage of the foliage. The incidence of the disease was recorded in the succeeding summer as total numbers of infections, irrespective of their severity. Bordeaux mixture sprays were always freshly prepared and were highly alkaline due to an excess of hydrated lime over copper sulphate in the proportions of 3 : 2 by weight ; the percentage figures below refer to their copper sulphate concentration.

Evaluation of bactericides

Comparison of Bordeaux mixture with related preparations (Plot E23)

In the original experiments(7) Bordeaux mixture had been used empirically, and the purpose of the present work was to see whether it might with advantage be replaced by other preparations. Sprays were applied twice each year, in the spring at white-bud, and in the autumn just before general leaf fall. The treatments were (spring spray first, autumn second) :

1. Bordeaux mixture (BM) at 0·6 per cent and 1·0 per cent (0·15 and 0·25 per cent Cu). This corresponds to the basic schedule of Montgomery and Moore(7).
2. Bordeaux mixture at 0·2 and 0·4 per cent (0·05 and 0·10 per cent Cu).
3. Cuprous oxide (CuO) preparation at 0·1 and 0·2 per cent Cu.
4. As 3, at 0·05 and 0·1 per cent Cu.
5. Copper oxychloride (COCl) preparation at 0·50 and 0·1 per cent Cu.
6. A dry Bordeaux powder (BP) at 0·15 and 0·25 per cent. Cu.
7. Hydrated lime (L) alone, at same concentrations as in No. 1.
8. Zinc-lime Bordeaux (ZBM), at 0·15 and 0·25 per cent Zn (using zinc sulphate instead of copper sulphate as in No. 1).

* Paper presented by the senior author at the 4th International Congress of Crop Protection, Hamburg, Sept. 1957.

Hydrated lime (No. 7) was included because of evidence that the bacterial activity of BM might be partly related to its high alkalinity (8).

The experiment was continued for six consecutive seasons, 1943-8, but general cankering was first evident in 1946. The results for 1946-8 are summarized in Table I.

TABLE I

EFFECT OF BACTERICIDES ON TOTAL CANKER INFECTION (MEAN NO./TREE), 1946-8 (VARIETY SCHRECKEN)

Treatments	1 (BM)	2 (BM)	3 (CuO)	4 (CuO)	5 (COCl)	6 (BP)	7 (L)	8 (ZBM)
Canker infections	4·5	5·0	6·9	6·7	6·0	5·2	6·8	5·3

Non-significant differences are bracketed

Although fewest cankers occurred under the Bordeaux treatments (1, 2, 6, and 8), there was no clear evidence of differences in merit among the various preparations. There were indications, from comparison with infection on unsprayed trees not included in the experimental design, that the basic schedule (treatment 1) had given a lower level of control than that obtained in the original experiment. The schedule was therefore re-examined in a later experiment.

Preliminary trials with streptomycin (Plot C5)

Preliminary trials with streptomycin were laid down in 1954 following reports of the successful use of the antibiotic against other bacterial diseases of tree fruits, notably fire-blight of apple (11) and blast of stone-fruits (6). The results of these trials have already been reported (5), but the following is a brief summary of the effects of streptomycin on canker infection.

In 1954, two foliar sprays of streptomycin sulphate (potency 200 i.u./ml.) in the latter half of September significantly reduced the numbers of cankers by approximately 72 and 52 per cent on the varieties Napoleon and Roundel respectively, compared with unsprayed controls. In the following year, in a re-randomized trial, significant reductions of 69 per cent on Napoleon and 59 per cent on Roundel occurred from two sprays of streptomycin hydrochloride (220 i.u./ml.) applied on 2nd September and 4th October respectively. These may have been assisted by three earlier sprays during blossom, which gave a highly effective control of the leaf-spot phase of the disease.

These results compared favourably with those from Bordeaux mixture in another trial (cf. Table II). In 1955, however, when it was possible to make a direct comparison within the same trial, streptomycin proved no better than early autumn applications of low-strength Bordeaux mixtures (see later), and there were indications that it was in fact less effective, particularly against the more severe forms of the disease (2).

Experiments on the timing of spray applications

Defoliant sprays (Plot E23)

Because natural leaf fall in cherry takes place slowly over a protracted period, it seemed probable that the infection period might be a long one. It had been observed previously (7) that a September spray of 1·0 per cent Bordeaux mixture accelerated leaf abscission and considerably shortened the leaf-fall period. In the following experiment advantage was taken of this as a possible means of improving canker control. A spray was applied in the second half of September, and 3-4 weeks later when premature leaf fall was imminent, it was followed by a second spray to blow off the leaves and protect the leaf scars. This schedule was compared with two others and with unsprayed controls, giving four treatments as follows :

1. Two sprays, in the latter half of September and in October, as above.
2. A single spray at the beginning of normal leaf fall (usually mid-October).
3. A single spray during general leaf fall (usually in November).
4. Unsprayed controls.

All sprays were of 1·0 per cent Bordeaux mixture. The entire plot, including the unsprayed control trees, received routine 0·6 per cent Bordeaux mixture at white-bud for the control of leaf-spot ; treatment 2 therefore corresponded exactly to the basic schedule recommended by Montgomery and Moore (7).

The experiment was continued over a period of three years (1951-3) on the plot of Schreckens (E23) used for the comparison of bactericides, and employed a similar statistical design, but with eight instead of four replications ; in practice some flexibility in the timing of spray applications was necessary due to seasonal variations in the onset of leaf fall, the effects of the September defoliant spray, and weather conditions.

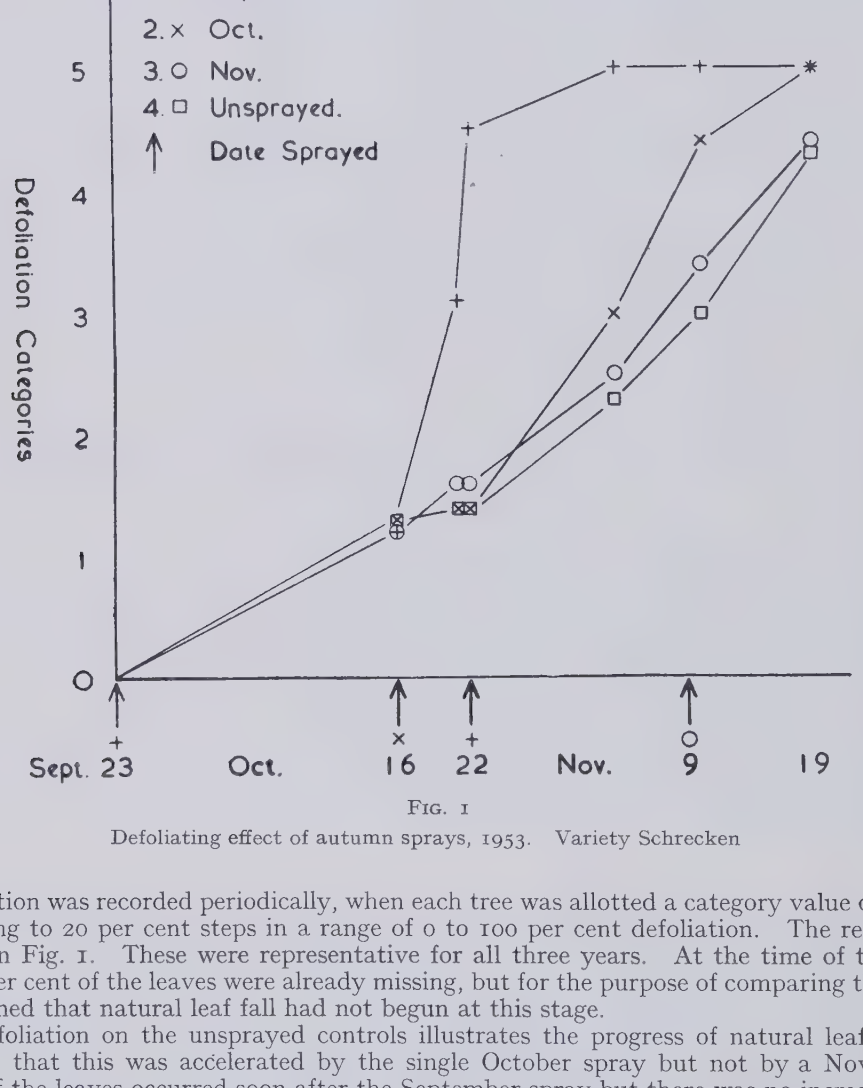

Fig. 1

Defoliating effect of autumn sprays, 1953. Variety Schrecken

Defoliation was recorded periodically, when each tree was allotted a category value of from 0 to 5 corresponding to 20 per cent steps in a range of 0 to 100 per cent defoliation. The results for 195 are shown in Fig. 1. These were representative for all three years. At the time of the first spra about 0·5 per cent of the leaves were already missing, but for the purpose of comparing the treatment it was assumed that natural leaf fall had not begun at this stage.

The defoliation on the unsprayed controls illustrates the progress of natural leaf fall ; it wil be observed that this was accelerated by the single October spray but not by a November spray Browning of the leaves occurred soon after the September spray but there was no increase in the rat of defoliation until 3-4 weeks later. Heavy defoliation followed the second application in October when many of the leaves were removed by the impact of the spray. Thereafter the process continue rapidly and was virtually complete by the end of October. At this stage natural defoliation ha reached only about a 50 per cent level and was still incomplete by the third week in November. A illustration of the contrast as seen in the plantation in the first year, 1951, is shown in Fig. 2.

The effects of sprays on canker infection for 1951-3 are shown in Table II.

A single spray in November during general leaf fall was ineffective. When treatments 1 and were compared, there were no demonstrable differences between the effects of the single Octobe spray and the combined September-October sprays. Only the latter, however, gave significan control, the difference between this treatment and the unsprayed control just reaching the level o significance in 1952 and again in 1953. It seems probable, therefore, that the September spray ha

TABLE II

EFFECT OF AUTUMN SPRAYS ON CANKER INFECTION (MEAN NO./TREE), 1951-3 (VARIETY SCHRECKEN)

Year of treatment	Treatments			
	1 Sept. and Oct.	2 Oct.	4 Nil	3 Nov.
1951	8·4	7·8	13·4	12·7
1952	5·1	6·9	13·3	16·7
				(P<0·05)
1953	15·1	23·2	31·9	34·2
				(P<0·05)

Non-significant differences are bracketed

a real effect. Evidence from later experiments supports this, but suggests also that the effect may have been due to the control of early infection and not necessarily to the shortening of the leaf-fall period.

Early autumn sprays

The use of early autumn sprays was approached from studies on fundamental aspects of the disease cycle. These confirmed the leaf scars as the main avenues of autumnal infection and drew attention to the importance of inoculum concentration in leaf-scar infection (1, 3). From observations on natural leaf fall and experimental inoculations at different times in the autumn, it was further concluded that natural infection probably began in early September or before, and continued until the onset of general leaf fall in the latter half of October, after which few infections occurred (3).

The bearings this had on disease control were as follows :

1. Sprays applied during general leaf fall were likely to occur after the main infection period and therefore to be ineffective. This appears to be borne out by results in the previous experiment (cf. November spray, Table II).

2. The first spray should be applied at the beginning of September or earlier, and in view of the long infection period, should be supplemented by at least one further spray after a suitable interval.

A schedule based on 2 above was tested in 1955 on six-year-old trees of the varieties Napoleon and Roundel (Plot C5). The first Bordeaux spray was applied on 2nd September, with a second spray on 4th October. To avoid premature defoliation the sprays incorporated cotton-seed oil (0·75 per cent v/v) and were used at low concentrations (0·2 and 0·4 per cent respectively).

The results are shown in Table III.

TABLE III

EFFECT OF EARLY AUTUMN SPRAYS ON CANKER INFECTION (MEAN NO./TREE), 1955 (VARIETIES NAPOLEON AND ROUNDEL)

Variety	Unsprayed	Sprayed
Napoleon	15·0	2·3 P<0·001
Roundel	12·8	3·3 P<0·01

On both varieties the sprays had a highly significant effect, the reduction in disease, approximately 85 per cent on Napoleon and 75 per cent on Roundel, being the best experimental control so far achieved ; this was reflected in the numbers of branches killed by girdling cankers, namely 10 on the 12 unsprayed trees of Napoleon, including several main branches, compared with one small lateral branch on the 12 sprayed trees.

Current experiments are tending to confirm the value of an early autumn schedule, but further work is planned before final conclusions are drawn.

Spring and summer sprays

These experiments were not concerned with the testing of control measures as such, but were designed to provide information on the effects on canker infection of sprays applied at varying times in the spring and summer. They were carried out on small, summer-pruned, pyramid trees of

Napoleon on F12/1 specially grown for the purpose (Fig. 3), and planted as maidens in 1951 at intervals of 4 ft in rows 8 ft apart. This arrangement arose out of similar developments for apple spray trials (10), and was a departure from the conventional type of field plot described earlier. Its main advantage was that it enabled a large number of trees to be grown in a comparatively small area, thus providing both for economy of land and good replication of treatments ; in the experiments below, for example, six different treatments were tested, each replicated 16 times on single-tree plots.

The trees were first used in 1954 to investigate the cumulative effects of successive spring and summer sprays. Treatments 1-4 (Table IV) were of Bordeaux mixture, at 0·6 per cent, with spreader at white-bud (15th April), and at 0·4 per cent, with cotton-seed oil at 0·75 per cent by volume, at petal-fall (13th May) and thereafter.

TABLE IV

TIMES OF SPRAY-APPLICATION

Treatment no.	Date(s) applied
1	15th April;
2	15th April and 13th May;
3	15th April, 13th May, and 27th May;
4	15th April, 13th May, 27th May, and 27th July;
5	as 3, but with copper oxychloride (1 per cent Cu) throughout;
6	nil

Sprays were applied from a small petrol-driven pump at about 50 p.s.i. pressure and one quart of spray per tree ; a light screen was used to arrest drift. Treatment 5 was a concentrate spray applied at about $\frac{3}{4}$ fl.oz. per tree in small droplets from a paint gun. In terms of metallic copper the amount applied per tree by this method was only one-fifth of that in treatment 3.

In 1955 the effects of single sprays at different times in spring and summer were tested. The treatments, re-allocated to the trees in such a way as to allow for any residual effects from the previous year, were :

Treatment : 1 22nd April (white-bud)
2 11th May (petal-fall)
3 20th June
4 2nd August
5 20th September
6 unsprayed controls.

All the sprays were 0·4 per cent BM, with 0·75 per cent by volume of cotton-seed oil, and were applied hydraulically as in 1954.

The results of the two experiments are summarized in Table V.

TABLE V

EFFECT OF SPRING AND SUMMER SPRAYS ON CANKER INFECTION (MEAN NO./TREE), 1954-5 (VARIETY NAPOLEON)

	Treatments					
1954	4 April May × 2 July	3 April May × 2	2 April May	5 April May × 2 (conc.)	6 Nil	1 April
	3·5	3·6	4·6	5·7	9·2	9·4
	(3·5 – 5·7)			(5·7 – 9·4)		
						P<0·01
1955	3 June	4 Aug.	5 Sept.	1 April	6 Nil	2 May
	5·0	5·0	5·4	10·6	11·4	11·6
	(5·0 – 5·4)			(10·6 – 11·6)		
						P<0·001

Non-significant differences are bracketed.

Fig. 2.

A four-tree plot of Schrecken cherry defoliated by 3rd November after Bordeaux sprays on 26th September and 24th October 1951

FIG. 3

Small, pyramid Napoleon cherry trees in August 1957: left, before pruning; right, after pruning.

In both years the April (white-bud) spray was ineffective. Response to the mid-May (petal-fall) spray was variable, its effect perhaps depending on seasonal conditions. When the results for both years are considered together it is clear that spraying at any time from the second half of May till September reduced the incidence of cankers in the autumn. The implications of these results will be discussed later. The copper oxychloride concentrate sprays tested in 1954 (treatment 5) were somewhat less effective than hydraulic sprays of BM (treatment 3), but nevertheless showed possibilities in view of the smaller amount of copper applied by this method.

Discussion

Perhaps a most significant feature of these investigations has been the fact that, in one or other of the experiments, control of cankers was achieved by spraying at any stage from petal-fall to mid-October. Control from sprays applied during the main infection period, i.e. in the autumn, is not difficult to understand, but the effect of the earlier sprays requires some explanation.

Throughout the growing season, pathogenic bacteria are present on the leaf surfaces in numbers which occasionally exceed a million per leaf. They are washed off by rain, and in the autumn provide the main source of infection for leaf scars. By a standard leaf-washing technique it has been possible to enumerate leaf-surface bacteria and thus to arrive at an estimate of the inoculum available for infection at any given time. This method has been used to investigate the surface activity of bactericides (2). With Bordeaux mixture the immediate effect of the spray was to eliminate the pathogen, or substantially to reduce its numbers on the leaf surfaces, but within a week bacteria re-appeared in the leaves and thereafter their numbers steadily increased. The ' build-up ' of inoculum was comparatively slow, however, and the effects of the sprays persisted long after the residues had disappeared from the trees, and frequently for the remainder of the season. The final result of summer sprays, therefore, was to reduce the number of bacteria available for infection in the autumn. Since leaf-scar infection is dependent on inoculum concentration (3), the implications of this will be obvious. In this connexion it is worth mentioning that April (white-bud) sprays, which failed to control cankers (Table V), have been shown to have no effect on the leaf-surface populations. There was also a striking parallel, in the experiment on dwarf pyramids in 1954, between the incidence of cankers and the numbers of bacteria on the leaves on 18th October, the relative numbers for the different treatments, arranged in order of increasing canker infection (as Table V) being : 1, 10, 27, 30, 49, 58.

It seems clear from these investigations that the problem of control is basically one of reducing inoculum prior to or during the period of autumn infection. While this may be achieved by spraying at any time after petal-fall, the most effective spray might logically be one applied just before infection begins, and in view of the long infection period this would probably need reinforcement by additional sprays to prevent the build-up of inoculum on the leaf surfaces. On this basis the main problems in field control are to determine the optimum timing of the first application and the minimum number of subsequent applications necessary to maintain its effect ; experiments designed to test these factors are now in progress.

Although at present it seems probable that substantial improvement in control is most likely to come from readjustments in the time and frequency of spraying, the possibility of using improved bactericides has still to be considered. None so far tested in the field has proved better than Bordeaux mixture, and preference for this material is probably justified on the basis of laboratory tests, which have shown it to be outstanding amongst insoluble copper compounds as a bactericide (8). Bordeaux mixture, however, has not won universal favour in commerce because it is troublesome to prepare and may have a deleterious effect on spray machinery. Of the possible alternatives, only streptomycin has been adequately tested, but the results so far do not suggest any marked superiority over Bordeaux mixture for the control of canker infection. The use of streptomycin is complicated by other factors and its full potentialities are at present difficult to assess (4).

Field trials on the control of bacterial canker of cherry are complicated by the considerable variation in the incidence of the disease from tree to tree, and the consequent need for good replication to show even large differences between treatments. In conventional field trials the number of treatments it is possible to test simultaneously is therefore limited. The development of small plots employing pyramid trees shows promise, and it should prove valuable for testing treatments prior to their examination in larger-scale field trials, although the possible influence on autumn infection of removing some of the foliage in summer pruning may have to be taken into account in assessing results on these small trees.

Summary

Bacterial canker, caused by the bacterium *Pseudomonas mors-prunorum* Wormald, has two distinct stages in its life cycle : a canker stage developing in autumn and winter through wounds

and leaf scars on shoots, spurs, and branches ; and a leaf-spot stage in spring and summer. Bacteria are exuded from cankers in the spring, and may infect the leaves in suitable weather conditions. Throughout the summer large numbers of bacteria persist on the leaf surfaces, independently of leaf-spot, and provide the inoculum for canker infections in the autumn. Control of the canker stage is based on spraying, first, to kill the bacteria on the surfaces of the leaves, and later, to protect the leaf scars.

In this paper the authors present a review of experiments made over many years at East Malling on the effects of various sprays on the leaf-surface populations of the causal organism, the timing of autumn spray-applications to protect the leaf scars, and the comparative effectiveness of the standard copper sprays and the antibiotic, streptomycin.

References

(1) Crosse, J. E. (1956). Bacterial canker of stone-fruits. II. Leaf-scar infection of cherry. *J. hort. Sci.*, **31**, 212-24

(2) ——— (1957). Streptomycin in the control of bacterial canker of cherry. *Ann. appl. Biol.* **45**, 226-8.

(3) ——— (1957). Bacterial canker of stone-fruits. III. Inoculum concentration and time of inoculation in relation to leaf-scar infection of cherry. *Ann. appl. Biol.*, **45**, 19-35.

(4) ——— (1957). Trials with the antibiotic streptomycin for the control of bacterial canker of cherry. *Rep. E. Malling Res. Sta. for 1956*, 170-2.

(5) ———, and Bennett, M. (1957). Preliminary field trials with streptomycin for the control of bacterial canker of cherry. *Plant Path.*, **6**, 31-5.

(6) Dye, D. W. (1954). Preliminary field trials to control blast of stone-fruit (*Pseudomonas syringae* van Hall). *N.Z. J. Sci. Tech.*, (A), **36**, 331-4.

(7) Montgomery, H. B. S., and Moore, M. H. (1945). The control of bacterial canker and leaf spot in sweet cherry. *J. Pomol.*, **21**, 155-63.

(8) ———, and Shaw, H. (1942). Laboratory tests of bactericides on the plum and cherry bacterial canker organism (*Pseudomonas mors-prunorum*). *Ann. appl. Biol.*, **29**, 399-403.

(9) Moore, M. H. (1946). Bacterial canker and leaf-spot of plum and cherry. A summary of present knowledge on control measures in Britain. *Rep. E. Malling Res. Sta. for 1945*, 134-7

(10) ——— (1954). Field methods for testing fungicides for apple and pear trees. *Comptes rendus IIIe Congrès International de Phytopharmacie, Paris*, 1952, **2**, 628-33.

(11) Winter, H. F., and Young, H. C. (1953). Control of fire-blight of apples in Ohio in 1953. *Plant Dis. Reptr.*, **37**, 463-4.

(12) Wormald, H. (1937). Bacteriosis of stone-fruit trees in Britain. VI. Field observations on bacteriosis of sweet cherry trees. *J. Pomol.*, **15**, 35-48.

THE INFLUENCE OF EARLY SPRING SPRAYS ON THE INCIDENCE OF APPLE MILDEW

By M. H. MOORE and MARGERY BENNETT

The difficulty of controlling apple mildew (*Podosphaera leucotricha* (Ell. and Everh.) Salm.) in recent years has raised the question of the part played by pre-blossom sprays in the effectiveness of control measures. There seems to be general agreement as to the merits of post-blossom sulphur sprays, and more recently of 2:4-dinitro-6-(1-methyl-*n*-heptyl) phenyl crotonate (karathane) also ; moreover, there is evidence (1) that a pink-bud lime-sulphur spray helps to reduce the potency of the disease. The merit of sprays at green-cluster, or even earlier when the buds are swelling or bursting, is more debatable.

Lime-sulphur applied when peach buds are swelling is usually very effective against leaf curl, a disease caused by a fungus (*Taphrina deformans* (Berk.) Tul.) that perennates in winter apparently much as the apple mildew fungus does, and this analogy prompted the investigation described below. It was supplemented by comparing lime-sulphur with 3:5-dinitro-*ortho*-cresol in petroleum oil, for this spray, applied at bud-burst, was at that time regarded as an essential component of many commercial apple spray programmes, although its use has declined since in favour of spring sprays of BHC/DDT and the summer ovicides.

Experiments, 1953-8

Experiments were conducted on a 320 ft E. to W. row of the mildew susceptible M.III rootstock, unworked and grown as a hedge (2). To preserve possible cumulative effects of the treatments, however, the stocks in this instance were not cut down to the ground every year, but were pruned once only, in autumn 1955. Following a pilot trial in 1953 on an older row of M.III stocks that were to be grubbed, the following treatments were compared from March 1954.

Treatments, 1954-8

1. Dinitro-*ortho*-cresol (DNC) emulsion containing 95·7 per cent winter-grade petroleum oil and 3·3 per cent DNC, at 3 per cent by volume at *bud-burst**. The diluted spray thus contained 2·9 per cent oil and 0·1 per cent DNC.
2. Lime-sulphur (LS) at 2½ per cent by volume, with Aerosol OT at 0·005 per cent as spreader, at *bud-burst*†.
3. Lime-sulphur at 2½ per cent by volume, with spreader as in No. 2, at *green-cluster*.
4. Unsprayed controls.

Note : Timing advanced to bud-swelling from 1956* and 1957†, but for convenient reference in the paper the term bud-burst is used.

The treatments were randomized in contiguous 16 ft plots in five replications, and applied with a 1½-2 h.p. hydraulic machine ; screens were manipulated to prevent spray-drift. All plants were sprayed with 5 per cent tar oil in the dormant period each year as routine treatment for aphid control.

Records

The number of naturally mildewed buds and shoots on each plot was recorded in April or early May every year ; later in summer the percentage of infected leaves was recorded on 20 random shoots per plot to see to what extent any effects of the sprays had persisted. Apple scab was similarly recorded.

Results

The summarized data of the spring records of mildew infections in relation to the four treatments over five successive seasons are shown in Table I.

Clearly only the DNC-petroleum appreciably reduced the numbers of mildewed buds recorded within a few weeks after the bud-burst sprays had been applied. Lime-sulphur applied at the same time had no effect over the period except in the final year, 1958, when it showed a significant reduction compared with the controls ; DNC-petroleum, however, showed a further significant reduction when compared with lime-sulphur.

TABLE I

MEAN NUMBER OF MILDEWED BUDS AND SHOOTS PER PLOT, 1954-8

Recorded	Bud-burst (1) DNC-petr.	Bud-burst (2) LS	Green-cluster (3) LS	(4) Nil	Sig. diff. (P<0·05)
Spring 1954	20·2	26·4	12·2	22·8	n.s.
Spring 1955	26·8	52·6	43·6	55·8	25·5
Autumn 1955	43·0*	49·4*	49·4*	53·2*	n.s.
Spring 1956	5·6	12·6	10·2	14·0	4·9
Spring 1957	47·0	90·0	96·6	111·6	48·2
Spring 1958	66·8	155·8	188·6	214·2	39·0
Mean ..	*33·3*	*67·5*	*70·2*	*83·7*	

* Infections recorded on shoots removed in pruning

These early sprays were not supported by summer applications of sulphur, which are standard practice for mildew control, and therefore the disease steadily increased on the foliage every season after spraying (Table II).

TABLE II

MEAN PERCENTAGE OF MILDEWED LEAVES/SHOOT ON 20 EXTENSION SHOOTS PER PLOT IN MID-SUMMER 1954-7

Recorded	Bud-burst (1) DNC-petr.	Bud-burst (2) LS	Green-cluster (3) LS	(4) Nil
1954	36	37	46	36
1955	57	56	86	61
1956	24	26	32	27
1957	69	74	64	73
Mean	*46·5*	*48·3*	*57·0*	*49·3*

Apple scab infection was negligible except in 1955, when the single green-cluster lime-sulphur spray showed slight control, as would be expected, but the bud-burst sprays were ineffective (Table III).

TABLE III

MEAN PERCENTAGE OF SCABBED LEAVES/SHOOT ON 20 EXTENSION SHOOTS PER PLOT IN MID-SUMMER 1955

Bud-burst (1) DNC-petr.	Bud-burst (2) LS	Green-cluster (3) LS	(4) Nil	Sig. diff. (P<0·05)
28·2	23·6	18·9	27·8	9·3

Discussion

Lime-sulphur applied at bud-burst had no effect on the numbers of buds growing out with over-wintered mildew. When the spraying was advanced to bud-swelling in 1957, there was no improvement at first, but a significant reduction occurred following a similar spray the next (and final) year, 1958. It was, however, not commensurate with the high degree of control usually reported for a similar spray against leaf curl of peach, neither did it match the mildew control shown by the DNC-petroleum. This oil spray also had no effect on random distribution of mildew in the first year, 1955, but gave a significant reduction every year afterwards, whether applied at bud-burst or swelling.

These observations imply some cumulative effect of the single spray application on the same plot from year to year, and a reflection of it might therefore be expected in the data relating to infected leaves on extension shoots in summer, as these are usually a bridge to overwintering bud-infection. None was apparent, however (Table II), and the nature and extent of any cumulative effect there may have been therefore remains problematic. The success of the single application of DNC-petroleum was evidently due chiefly to its direct action every year on bud-infection at an early stage of bud

movement in spring. Cumulative effect would perhaps be encouraged were later mildew development controlled by suitable protective spraying, not included in these experiments.

There is no evidence to show whether or not both major components of the DNC-petroleum spray are necessary ; it may well be that either component would suffice. These points can be settled only by further investigation.

The action of the green-cluster lime-sulphur spray would be of a different kind in protecting healthy foliage from scab and mildew for a time, with possibly some eradicant action also against any fresh infection already present. As with the spray applied to the buds, support from summer sprays is necessary to consolidate any initial advantage.

Summary

An emulsion concentrate of DNC-petroleum oil, diluted (at 3 per cent) to give a spray containing 2·9 per cent of winter-grade oil and 0·1 per cent DNC, was applied at bud-swelling or bud-burst to the same plots of unworked M.III rootstocks over a period of five years, and significantly reduced the numbers of buds that grew out with overwintered mildew within a few weeks afterwards. A similar spray of lime-sulphur at 2½ per cent reduced infection in only the final year, and the reduction was of a much lower order. Neither material showed any effect on apple scab (in 1955), but lime-sulphur applied only at green-cluster slightly reduced infection.

References

(1) Moore, M. H. (1930). The incidence and control of apple scab and apple mildew at East Malling. *J. Pomol.*, **8**, 229-247 and 283-304.

(2) ——— (1952). An intensive field method for testing fungicides for apple trees. *Rep. E. Malling Res. Sta. for 1951*, 139-47.

THE TIMING OF SPRAY TREATMENTS FOR THE CONTROL OF STORAGE ROT OF APPLE CAUSED BY *GLOEOSPORIUM* SPP.

By M. H. MOORE and K. L. EDNEY*

In recent years very severe losses have been experienced in the storage of certain varieties of apples, particularly Cox's Orange Pippin, through rotting caused by *Gloeosporium* rot fungi. Two species, *G. perennans* Zeller and Childs especially, and *G. album* Osterwalder, are primarily responsible for the rotting, which occurs chiefly at the lenticels (4, 6, 15, 16).

Investigation into the biology of these fungi has established that spore-inoculum is available on cankers and infected stubs on the trees at any time from fruit setting to harvest (3, 4, 7), and that fruit infection can be established at least from early July (5). These infections, however, do not develop and form a rot until the fruit has been stored.

To control infection by spraying, it was necessary to find the best times for applying the sprays over the long period during which the fruits could be naturally contaminated. A sequence of protective sprays seemed likely to be required, and as captan was already known to give some control (11, 13), this material was chosen for the following experiment, undertaken in a commercial plantation at Horsmonden in the Weald of Kent.

Experiment, 1955-6 and 1956-7

Trees and layout

The Cox's Orange Pippin trees, pollinated by Worcester Pearmain, were on M.II rootstock and had been planted in 1937. They were 24 ft apart in diagonal rows, grassed down, and in very good condition. Single-tree replicates of each of the four treatments were randomized in twelve blocks, and in the second season the treatments were re-randomized on the same 48 trees. In both years all trees had colloidal sulphur sprays for scab before the spraying against *Gloeosporium* began.

Spray treatments

Three captan spray schedules were applied as follows and compared with an unsprayed control :

1. in July (Jy), August (A), and September (S) ;
2. in August and September ;
3. in September only.

The captan was a commercially formulated 50 per cent wettable powder, sprayed at 0·2 per cent (0·1 per cent of active ingredient) on all occasions. Sprays were applied by 2-nozzle lance from a trailer hydraulic machine at 300 p.s.i. pressure ; each tree required about 4 gal. of diluted spray for good cover, and was well sprayed to run-off.

Dates of spraying

1955	1956
15th July	21st July
16th August	17th August
14th September	14th September

Records

The crop was picked by the farm staff (23rd-24th September 1955 ; 28th-29th September 1956), and the boxes stacked beneath the trees. Samples of 100 fruits from each of the 48 trees were then chosen by the experiment staff, an appropriate number of fruits being drawn from all layers in one corner of each box comprising the crop. Fruits that clearly would not store well because of blemish were not included in the samples. Every sample of 100 was divided into four sub-samples, each of 25 fruits, which were put into bags and stored as soon as possible at 37°F. The sub-samples were examined serially at four periods during storage, and records made of the number of fruits showing *Gloeosporium* rots, the number of rot lesions, and the species responsible for each.

* D.S.I.R., Ditton Laboratory, Kent.

Results

The data in Table I are the percentage number of apples with any *Gloeosporium* rot at four dates of inspection, each value being based on one sub-sample of 25 fruits. For analysis the data were transformed to angles of equal information, also shown in the table ; significant differences ($P < 0.05$) apply to the angles. The relative incidence of the two species, *G. perennans* and *G. album*, is shown in Table II.

TABLE I

EXTENT OF FRUIT-ROTTING

Date inspected	Sprayed in: Jy. A. S.		A. S.		S.		Not sprayed		Significant difference ($P<0.05$)
	%	*Angles*	%	*Angles*	%	*Angles*	%	*Angles*	
1955-6									
(1) 12th Dec. 1955 ..	1·6	*7·2*	2·4	*8·9*	3·5	*10·8*	5·4	*13·4*	
(2) 3rd Jan. 1956 ..	1·8	*7·6*	3·5	*10·8*	3·5	*10·8*	11·1	*19·5*	↑
(3) 31st Jan. 1956 ..	3·8	*11·2*	9·6	*18·0*	13·6	*21·6*	29·2	*32·7*	5·23
(4) 3rd March 1956 ..	10·1	*18·5*	18·6	*25·5*	21·8	*27·8*	65·3	*53·9*	↓
Mean	*3·7*	*11·1*	*7·4*	*15·8*	*9·2*	*17·7*	*24·9*	*29·9*	2·49
1956-7									
(1) 14th Dec. 1956 ..	5·3	*13·2*	5·5	*13·5*	3·9	*11·4*	8·1	*16·5*	
(2) 4th Jan. 1957 ..	8·9	*17·3*	9·0	*17·4*	15·0	*22·8*	14·0	*22·0*	↑
(3) 18th Jan. 1957 ..	13·1	*21·2*	18·3	*15·3*	22·2	*28·1*	37·4	*37·7*	6·17
(4) 1st Feb. 1957 ..	20·2	*26·7*	21·9	*27·9*	34·3	*35·8*	56·0	*48·4*	↓
Mean	*11·3*	*19·6*	*12·9*	*21·0*	*17·2*	*24·5*	*26·7*	*31·1*	3·42

TABLE II

NUMBERS OF ROT LESIONS CAUSED BY THE RESPECTIVE SPECIES

(EACH SINGLE VALUE IS FROM 300 (25 × 12) APPLES)

Date inspected	*G. perennans* Jy. A. S.	A.S.	S.	Nil	Total	*G. album* Jy. A. S.	A.S.	S.	Nil	Total
1955-6										
(1) 12th Dec. 1955	2	5	6	9	*22*	1	2	5	8	*16*
(2) 3rd Jan. 1956	1	5	7	24	*37*	3	6	5	16	*30*
(3) 31st Jan. 1956	5	7	16	33	*61*	7	26	23	56	*112*
(4) 3rd March 1956..	12	24	19	46	*101*	20	39	50	148	*257*
Total	*20*	*41*	*48*	*112*	*221*	*31*	*73*	*83*	*228*	*415*
1956-7										
(1) 14th Dec. 1956	16	12	11	20	*59*	1	6	2	7	*16*
(2) 4th Jan. 1957	27	25	42	39	*133*	3	5	8	13	*29*
(3) 18th Jan. 1957*	33	45	49	57	*184*	8	11	23	56	*98*
(4) 1st Feb. 1957	43	56	60	75	*234*	21	14	44	92	*171*
Total	*119*	*138*	*162*	*191*	*610*	*33*	*36*	*77*	*168*	*314*

* In addition on this occasion, both species were present on each of three lesions, but this was unusual.

Discussion

The following conclusions may be drawn from the analysis of variance of the data in Table I. For convenience, 1955-6 is referred to as Year 1 and 1956-7 as Year 2.

1. By the end of January rotting was more advanced in Year 2 than in Year 1. This may have been due to more rapid fruit senescence in Year 2, or to heavier orchard infection ; the data in Table II suggest that both factors may have operated. In Year 1 lesions associated with *G. album* were more numerous than those with *G. perennans*, but the position was reversed in Year 2.

2. On the whole the spray programme gave better control in Year 1. This may be chiefly because Year 2 was the wetter season (see Table III below), and evidently (Table II) favoured the development of *G. perennans*, which usually causes earlier rotting than *G. album* in store.

3. The relative merits of the spray programmes became more evident at the later inspections. In Year 1 a significant and substantial degree of control was shown by the September spray alone at all times after the first inspection. This was improved by the addition of the July spray, particularly at the two last inspections, but not by the August spray.

In Year 2 the pattern was reversed, for no control by the September spray was evident until the third inspection. There was additional control from the August spray, though this also was not evident until the third inspection, but the July spray did not improve upon this at any of the inspections.

That these differences between the two seasons may be related to differences in rainfall preceding and following the three dates of spraying is suggested by the data in Table III.

TABLE III

RAINFALL (IN.) AT HORSMONDEN BEFORE AND AFTER THE DATES OF SPRAYING

	July	→	July spray	→	August spray	→	Sept. spray	→	Harvest	Total
Year 1 (1955)		0·22		2·24		0·45		1·70		4·61
Year 2 (1956)		3·21		1·24		2·54		0·48		7·47

It will be seen that in Year 1 the two effective sprays, July and September, were each preceded by relatively dry periods and followed by wetter periods. In Year 2 the converse was true, and the July spray showed no effect, probably because the very wet period before any captan sprays were applied had already induced a heavy dispersal of inoculum. This time the August spray was partly effective, as it reduced the number of *G. album* infections recorded when they were rapidly developing after the second inspection, but had no comparable effect on *G. perennans* (Table II). The September spray was rather less effective than in Year 1, and, as with the August spray, its effect was almost wholly confined to *G. album*. There was 0·37 in. of rain on the day before picking began, and it would be possible for spores then washed on to the apples to continue to develop in store (4).

Although the sprays were applied at regular, long intervals not deliberately related to rainfall periods, the results strongly suggest that spraying was more effective before a relatively wet period than afterwards. Rain releases spores from infected stubs and cankers on the trees, but there was, however, no consistent evidence from experiment of a quantitative correlation between rainfall and spore-release (3).

As a basis for a successful spray programme, a captan spray in September evidently can give appreciable control, but it is often difficult to apply by conventional methods without risk of mechanical damage to the crop on laden branches, and should be augmented by earlier sprays, as shown also in Tasmania (13, 14), and in other trials in this country (8, 10, 11). The extent of the need for such sprays will depend largely on seasonal conditions. It seems clear that in a wet summer an interval of one month between successive sprayings may be much too long and might well be halved, especially for parts of the farm that have a history of *Gloeosporium*. Flexibility in the number and timing of sprays according to the seasonal circumstances would appear to be a more desirable aim than a rigid schedule of widely-spaced sprays.

As the rotting occurs chiefly when the fruits are in store, rarely when on the trees, it is perhaps surprising that a single spray applied just before picking does not suffice to destroy spores accumulated on the surfaces of the fruit throughout the season. Indeed, to dip the fruits in a fungicide after picking might appear to be an even better plan ; this has been tried, however, with indifferent results (1, 2, 9). In 1955, extra samples of all orchard-sprayed fruits, together with the controls, were dipped in 0·1 per cent captan after picking, but no further reduction in rotting was obtained. This result emphasizes that however effective the toxicant might be, the timing of its application is of first importance. While post-harvest dipping to increase the amount of captan on the surface of the fruit prior to storage is unlikely to be effective, it has been shown (10) that the level of captan deposit at picking time on fruit receiving three orchard sprays was higher than that on fruit receiving fewer sprays. Thus the earlier sprays may augment the effect of later ones by contributing to the ultimate residue.

The failure of dipping, and, in certain instances, of spraying, may be attributed to two main causes. The spores, or the appressoria developing therefrom after germination (5), may become lodged in parts of the lenticels that are inaccessible to the fungicide. Furthermore, it has been demonstrated (5) that in the initial development of *G. perennans* on the fruit an infection thread (hypha) is formed which penetrates the underlying tissue of the apple in certain instances. Wade (13) and Kienholz (6) have reported that latent infections may occur at a very early stage in the development of apple fruits. These types of latent infection would be unlikely to yield to late summer applications of fungicide in liquid phase, for without special formulation they would probably not penetrate the epidermal layers. Spencer and Wilkinson (12) however, have recently indicated that the use of the antifungal fumigant (2:4:5 trichlorophenoxythio)trichloromethane in the store can reduce the incidence of *Gloeosporium* rotting, and they anticipate further work along these lines.

Summary

Captan sprays were applied at 0·1 per cent of active ingredient to established Cox's Orange Pippin trees from July to September in an experiment continued during two seasons, 1955 and 1956. Samples of the fruits were stored at 37°F. and rotting due to *Gloeosporium perennans* and *G. album* was recorded at four serial inspections during the storage period.

A single spray in mid-September in both years gave a significant degree of control, and this was augmented in 1955 by an additional spray in mid-July, and in 1956 in mid-August. It is suggested that this variation is related to differing rainfall before and after spraying. In the wet summer of 1956 when the rotting due to *G. perennans* was more severe, control from three sprays at monthly intervals was less satisfactory than in the drier preceding summer. It is therefore suggested that a reduction in the interval between successive sprayings during unsettled weather might result in more effective control.

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References

(1) Anon (1955). *Rep. Fd. Invest. Bd, Lond.* 1954, 55.

(2) ——— (1956). *Ibid.*, 1955, 47.

(3) Corke, A. T. K. (1956). Bitter rot of apples : II. Seasonal variations in the development and sporulation of cankers of *Gloeosporium* spp. inoculated into apple branches. *J. hort. Sci.*, **31,** 272-83.

(4) Edney, K. L. (1956). The rotting of apples by *Gloeosporium perennans* Zeller and Childs. *Ann. appl. Biol.*, **44,** 113-28.

(5) ——— (1958). Observations on the infection of Cox's Orange Pippin apples by *Gloeosporium perennans* Zeller and Childs. *Ann. appl. Biol.*, **46,** 622-9.

(6) Fisher, D. F. (1925). A new apple rot disease (' Bull's-eye Rot ', caused by *Gloeosporium*, Zeller and Childs.) *Proc. Wash. St. hort. Ass.*, **21,** 44-8.

(7) Guthrie, E. J. (1957). A study of the dispersal of *Gloeosporium* spp. on apples. *Part II, Ph.D. Thesis, London Univ.*, 55-104.

(8) Hamer, P. S., and Hunnam, D. (1957). More results of trials with captan. *Grower*, **47,** 12, 746.

(9) Kienholz, J. R. (1956). Control of Bull's-eye rot on apple and pear fruits. *Plant Dis. Reptr.*, **40,** 10, 872-877.

(10) Marsh, R. W., and Edney, K. L. (1956). Spraying trials at Long Ashton, 1953-1956, for the control of *Gloeosporium* storage rot in Allington Pippin. *Ann. Rep. Long Ashton Res. Sta.*, 109-115.

(11) ———, Montgomery, H. B. S., and Edney, K. L. (1957). Experiments on orchard spraying for the control of *Gloeosporium* storage rots of apples. *Plant Path.*, **6,** 39-41.

(12) Spencer, D. M., and Wilkinson, E. H. (1958). A method of reducing the losses caused by *Gloeosporium* spp. in stored apples. *Nature, Lond.*, **181,** 1603-4.

(13) Wade, G. C. (1953). Ripe spot and target spot of apples. *Tasm. J. Agric.*, **24,** 14-19.

(14) ———, and Ward. J. R. (1956). The influence of fungicides and fruit maturity on the development of ripe spot and target rot of apples. *J. Aust. Inst. agric. Sci.*, **22,** 198-203.

(15) Wilkinson, E. H. (1943). Bitter rot of apples caused by *Gloeosporium album* Osterw. with special reference to the variety Allington Pippin. *Ann. Rep. Long Ashton Res. Sta.*, 81-9.

(16) ——— (1945). Perennial canker of apple trees in England. *J. Pomol.*, **21,** 180-5.

DENSITY, DEFENDER AND JANUS: THREE NEW WILT-TOLERANT HOPS

By J. F. WILSON

Since 1942 one of the aims of research on progressive wilt of hops, caused by *Verticillium albo-atrum*, has been to find new varieties for replanting affected gardens. Keyworth, Hitchcock and Goode (1) selected two Wye varieties bred by Prof. E. S. Salmon, OJ47 and OR55, later named Keyworth's Early and Keyworth's Midseason respectively (2). Both are tolerant to wilt, but Keyworth's Early is too susceptible to powdery mildew for commercial cultivation. Early trials with Keyworth's Midseason suggested that it was acceptable to the brewing industry; the seriousness of wilt infection in the Wealden area therefore created a great demand for this variety amongst growers, and its acreage increased rapidly between 1949 and 1953. By then, however, it was apparent that the brewers' demand for this variety was small and production therefore already excessive (3). It is thus evident that the eventual demand for a new variety cannot be forecast from the results of brewing trials limited to a few large breweries.

For many growers, however, growing hops on *Verticillium* infected land is essential to maintain basic quota economically, and to avoid over-production of any one variety it is desirable that several should be available. Since it became apparent that Keyworth's Midseason was not acceptable to the brewing industry only two varieties have been available in sufficient quantities to meet growers' demands, and the acceptability of these two is still uncertain. The release of the three new varieties described below should ease this acute shortage.

The earlier tolerant varieties including the two noted above were selected by Salmon for their cultural characters alone, their wilt-tolerance being discovered later (1). Deliberate breeding for this character was begun at East Malling by Keyworth and his associates in 1944 with the primary aim of producing tolerant males. Wilt-tolerant female hops were, however, produced incidentally and these were propagated for further test (*loc. cit.*).

Impetus was given to the further large-scale trial of the latter by the unpopularity of Keyworth's Midseason noted above and as a result, in the winters of 1956-7 and 1957-8 three of these (index nos. D1, D3, and J2) were released by this Research Station's Executive Committee to the Industry. At the time of release these varieties were named as follows:—D1, Density; D3, Defender; and J2 Janus (see p. 114).

A description follows of the later stages of trials on which the selection and release of these three varieties was based, together with an account of their brewing, cultural and distinguishing morphological characters as so far determined.

Farm trials

The final selection was, as with Keyworth's Early and Keyworth's Midseason, based on performance in 'block trials' on commercial farms under normal cultural treatment. Trials including Density, Defender, and Janus were established in gardens where it could be assumed that the soil was extensively infected and in dispersed localities providing some variation in environment. On all plots the incidence of wilt, and notes on the cultural and morphological characters of the varieties, were recorded throughout each season. Yield estimations were made annually from data supplied by the growers who also co-operated in making the crops available for brewing trials.

Details of localities, soil types, establishment dates and the size and number of these trials (which varied according to the availability of planting material) appear in Table I.

Wilt-tolerance

The annual incidence of wilt in the various plots (Table I) indicates that the earlier intensive tolerance tests had satisfactorily anticipated the behaviour of the three varieties under normal commercial conditions, and that they are comparable with Keyworth's Midseason in this essential character.

On most plots there were minor seasonal variations in the number of plants showing symptoms as previously reported (1). There was, however, a steady increase of wilt in Defender at Frittenden and Defender and Janus together with other tolerant varieties developed abnormally severe wilt in another trial. The incidence of wilt in Janus on the latter farm (not included in Table I) for the years 1954-1957 was 9·0, 12·0, 17·0, and 10·5 per cent; and in Defender for the years 1955-

TABLE I

WILT INCIDENCE 1950-1957

Variety	Locality	Soil type	No. hills recorded	Year of establishment	Per cent wilt							
					1950	1951	1952	1953	1954	1955	1956	1957
Density (D1)	Capel	Close-textured with compact pan. Nutrient status low.	281	1955(a)						Nil	Nil	0·4
	Frittenden	Moderately good and deep with localized drainage impedance.	259	1956(a)							0·4	0·8
	Marden	Deep, well-drained brick-earth alluvium.	337	1950(b)	0·3	1·5	1·0	Nil	Nil	Nil	0·3	Nil
Defender (D3)	Beltring	Fairly typical heavy ' Fuggle-land '.	346	1950(a)	1·2	1·2	0·6	0·9	0·3	0·3	0·3	1·5
	Frittenden	Very variable ; somewhat acid.	195	1955(b)						0·5	3·6	6·7
Janus (J2)	Beltring	Shallow, heavy and poorly drained ; a poor rooting medium.	347	1953(c)				2·0	0·6	0·3	1·7	0·6
	Capel	Close-textured with compact pan. Nutrient status low.	597	1954(a)					0·3	0·2	3·5	1·2
	Horsmonden	Very variable. Subject to drought.	633	1953(a)				0·5	Nil	Nil	Nil	Nil

(a) Planted after two-year ' fallow ' (i.e. crops other than known *Verticillium* hosts)
(b) Planted immediately after wilted Fuggle
(c) Planted after five years' cropping with Whitbread's Golding Variety

24·6, 32·9, and 44·5 per cent. The Janus plot followed a two-year fallow period, while the Defender plot followed immediately on wilted Fuggle which had been incompletely grubbed, so that there was a high proportion of ' rogue ' and mixed hills. Adjustment has been made for this in calculating the incidence of wilt, but even so the figures given may be too high.

Other occurrences of a similar apparent ' breakdown ' of tolerance have recently been confirmed and the cause, whether environmental or due to variation of the pathogen (4), is being studied.

Brewing value

The crops of seasons 1952-7 were, with certain exceptions, used in commercial brewery and small-scale trials organized by the Institute of Brewing in conjunction with the Brewing Industry Research Foundation. In the former, usually from four to six brewers made independent spring and autumn trials of a crop of any one variety. The summaries of the principal results of these trials in Tables II and III have been prepared from the published reports (5).

TABLE II

RESIN ANALYSES AND PHYSICAL CHARACTERS OF CONES

	Density (D1)	Defender (D3)	Janus (J2)
α-soft resins	Higher than controls*	Higher than controls	Similar to controls
Total soft resins	Higher than controls*	Higher than controls	Lower than controls
Cone size	Small	Small	No comments (therefore probably satisfactory)
' Rub '	Fair to good	Fair to good	Fair to good
' Aroma '	Mild and pleasant	Variable from ' good ', ' mild ' to ' coarse ', ' unpleasant '	Mild and pleasant

NOTE: Resin content described on the basis of averaged analyses of Institute of Brewing hop trials on following crops:

Density: 1952, 1954-6; Defender: 1952-6; Janus: 1953-6.

Physical characters based on the comments from the following numbers of examinations made in the above trials:

Variety D1—25 examinations; variety D3—24 examinations; variety J2—18 examinations.

* Comparison with controls (consisting of normal grist) made in resin analyses only.

TABLE III

SUITABILITY FOR COPPER AND DRY HOPPING*

	Density (D1)				Defender (D3)				Janus (J2)			
Substitution in normal hop grist:	%	%	%	%	%	%	%	%	%	%	%	%
Copper hopping	25	50	100		25	50	100		25	50	100	
Dry hopping				100				100				100
SPRING												
Total number of brewing trials	17	11	9 (4)	7	16	9	9 (4)	7	14	8	7 (4)	3
Number of times suitable ..	16	8	5 (3)	6	16	6	7 (4)	6	11	6	5 (3)	3
AUTUMN												
Total number of brewing trials	16	11	7 (4)	4	15	8	8 (4)	7	14	9	7 (4)	3
Number of times suitable ..	15	10	6 (4)	4	13	5	5 (3)	5	12	5	6 (3)	3

Figures in brackets refer to tests carried out at the Brewing Industry Research Foundation and are included in totals.

* Institute of Brewing and Brewing Industry Research Foundation Trials on following crops:- Density: 1952, 1954-6; Defender: 1952 (I. of B. only), 1953-6; Janus: 1953-6.

Fig. 1

(*Above*) Variety D1. Mid-upper lateral branch of hops. (*Below*): Variety Fuggle.

Fig. 2

(*Above*) Variety D1. Mid-upper lateral branch of hops. (*Below*): Variety Fuggle.

Fig. 3

(*Above*) Variety J2. Mid-upper lateral branch of hops. (*Below*): Variety Fuggle.

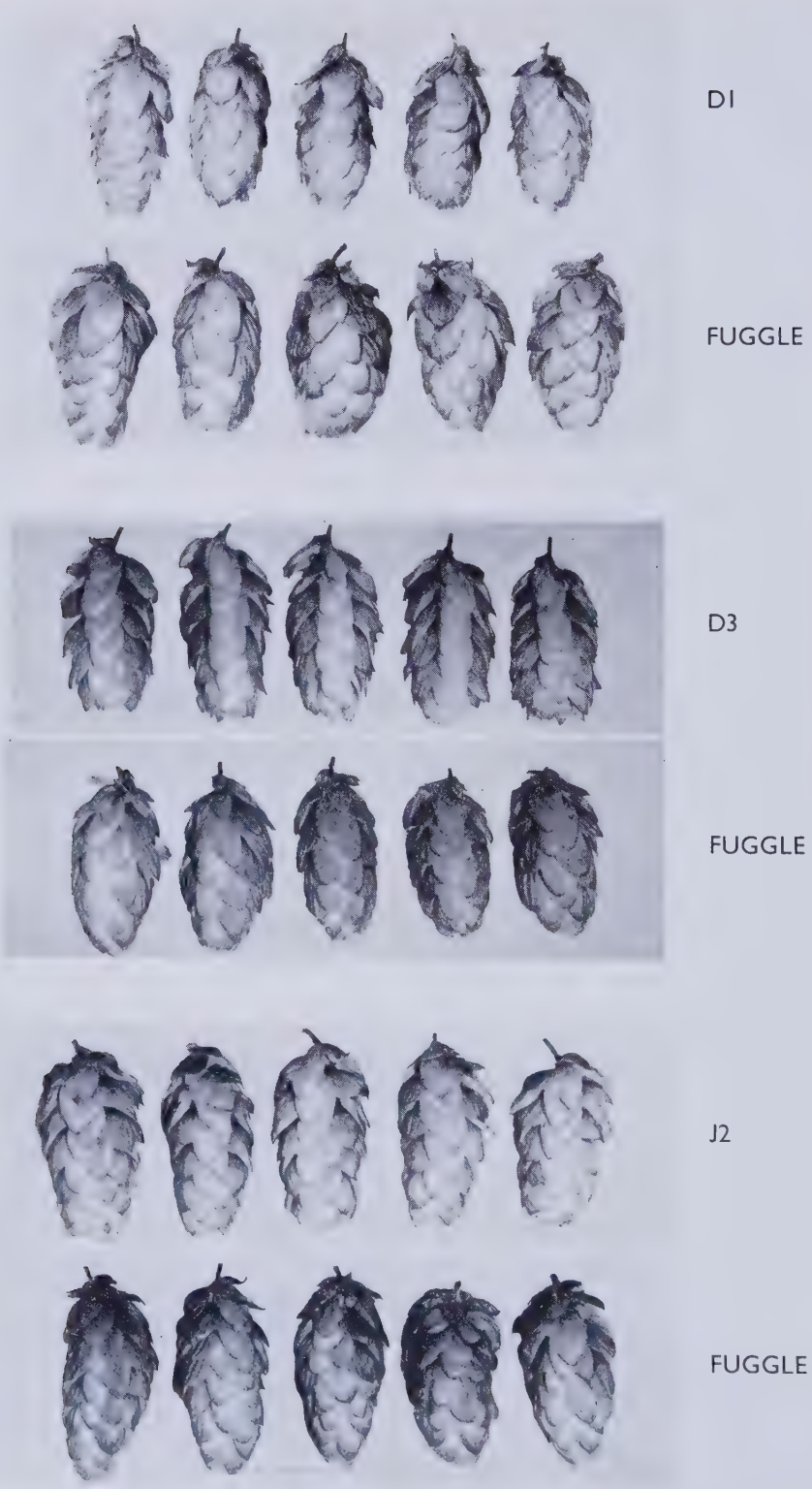

FIG. 4
Cones of varieties D1, D3 and J2, each compared with those of Fuggle grown on the same farm

In the brewery trials the new hops and normal grist controls were analysed for α- and total soft-resin content, and the physical characters of the new hops were examined. In brewery-scale copper-hopping trials they were incorporated in trial grists to replace the normal grist (usually on the basis of α-soft resin content) in proportions varying from 25 to 100 per cent. In early trials the varieties were tested in dry-hopping, usually by complete substitution for the normal grist in proportion to α-soft resin contents, in beers brewed with the control grist as copper hop. This was discontinued when the emphasis was placed on finding a substitute for Fuggle.

In the small-scale copper-hopping trials by the Brewing Industry Research Foundation, the new hops were normally used as complete substitutes for Fuggle, usually in proportion to α-soft resin contents.

It will be noted from the Tables that each variety has proved acceptable in some degree as a substitute in normal grist. Density and Defender are considered quite suitable for replacing 25 per cent of the grist but there is a tendency for acceptability to lessen at higher substitution rates. Janus received slightly fewer favourable reports than Density and Defender but it is, nevertheless, satisfactory, and it has the advantage that it was equally suitable at all substitution rates. The similarity in α-soft resin content of Janus and the control suggests that replacement might be made on a weight-for-weight basis.

The physical characters of the varieties suggest that, under traditional methods of market evaluation, samples of Density and Janus would fare better than Defender, but the evidence available on this point is conflicting.

Cultural Characters

Table IV

Cultural characters

	Density (D1)	Defender (D3)	Janus (J2)
Season	late-mid to late	early to early-mid	mid
Growth habit	vigorous	vigorous	moderately vigorous
Yield potential	apparently heavy	good	moderate
Reaction to :			
Downy Mildew	very susceptible	very susceptible	average susceptibility
Powdery Mildew	average susceptibility	average susceptibility	average susceptibility
Mosaic Disease	tolerant carrier	tolerant carrier	tolerant carrier

Density and Defender are seedlings of Keyworth's Midseason and Janus is a seedling of Whitbread's Golding Variety, and clear differences are just as great between varieties having a common parent as between those with no common parent. The desirable features of each variety tend largely to outweigh the less desirable, especially when physical characters or brewing qualities are considered. Thus Density, which ripens late and is very susceptible to downy mildew, has the compensating characters of high yield potential and compact cones likely to withstand damage by machine picking. Defender is similarly susceptible to downy mildew but has a good yield potential and ripens early. Janus, although of only moderate vigour and yield potential, is not very susceptible to downy mildew, and has a bearing habit suitable for machine picking ; it also has bold cones likely to enhance its market evaluation. Furthermore, resin analyses show that Janus might well replace Fuggle in brewing on a weight-for-weight basis.

The yields of the varieties in the trials are given in Table VI together with the types of soil on the plots.

The additional trial of Janus, established in the spring of 1954 on a silty loam soil, yielded in the years 1955-7 at the rate of 19, 10 and 17 cwt. per acre respectively.

Discussion

The brewing industry's demand for a new hop is usually small, either because it is suitable only for certain types of beer of limited output, or because of a generally conservative attitude towards possible substitutes for long-established varities such as Fuggle, even for use in blends.

Although it seems improbable that the three new varieties will be generally accepted as Fuggle substitutes, this is not a valid reason for withholding them from cultivation since each may find a limited demand with certain breweries sufficient to absorb the crop produced. The evidence suggests that all three are sufficiently wilt-tolerant to control the disease in the field and that each meets some of the requirements of both grower and brewer. The varieties were therefore released for commercial

cultivation and to ensure that healthy material would be available for this, virus-tested and *Verticillium*-free stocks (6) were allocated to commercial specialist propagators through the Propagation Committee of the Hops Marketing Board for multiplication and eventual issue to growers under the A-plus Health Certificate of the Ministry of Agriculture, Fisheries and Food.

The name given to each variety refers to a salient but, as in Defender, not necessarily exclusive, character of the variety, i.e.,

Density (D1) : low bushel/cwt. ratio,

Defender (D3) : good defences against progressive wilt,

Janus (J2) : dual-purpose (in brewing trials has done equally well against Golding or normal control grist).

One or more of these varieties should usefully augment the cropping of *Verticillium*-affected land by the two tolerant varieties at present most readily available (Bramling Cross and Whitbread's Golding Variety) to give a suitable sequence of harvesting. Alternatively the three varieties alone could provide a satisfactory cropping programme.

TABLE VI

YIELDS

Variety	Locality	Soil type	Calculated yield cwt./acre							
			1950	1951	1952	1953	1954	1955	1956	1957
Density (D1)	Capel	Close-textured with compact pan. Nutrient status low.						Not picked separately	Not picked separately	12·0†
	Frittenden	Moderately good and deep with localized drainage impedance.							Not picked separately	11·5
	Marden	Deep, well drained, brick-earth alluvium.		23	31	Not picked	33	11*	18	21
Defender (D3)	Beltring	Fairly typical heavy 'Fuggle land'.	6	18	16	14	22	26	14	19
	Frittenden	Very variable; somewhat acid.							11	22
Janus (J2)	Beltring	Shallow, heavy and poorly drained; a poor rooting medium.					8	16	3*	13
	Capel	Close-textured with compact pan. Nutrient status low.					2	13	5†	5†
	Horsmonden	Very variable. Subject to drought.					6	7·5*	10·5	13·5

* Acreage increased : this figure is an average which includes the new plantings.

† Plot almost completely defoliated by a hailstorm in early August 1956, with a probable carry-over effect to 1957.

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Mr. J. T. Legg was responsible for the virus-testing of the planting stocks and Miss C. L. Jary (N.A.A.S.) for the description of soil types.

Summary

Three new wilt-tolerant hop varieties have been released from the first of several breeding projects specifically designed for this purpose.

Density (D1) is a late hop of vigorous growth habit and high yield potential. The cones, although small, are of a compact nature likely to withstand damage by machine picking. The variety is extreme

TABLE V

DESCRIPTIVE CHARACTERS*

	Density (D1)	Defender (D3)	
Bine:			
Amount	Adequate.	Sparing.	Moder
Vigour	Good.	Good.	Moder
Colour	Green.	Green, sometimes with faint red tinting.	Green.
Leaves:			
Number of lobes	Commonly five, occasionally seven.	Commonly five.	Comm
Depth of indentation	Deeper than Fuggle.	Similar to Fuggle.	Simila
Petiole:			
Length	Similar to Fuggle.	Longer than Fuggle.	Shorte
Colour	Green.	Green, occasionally with faint red tinting at base.	Green.
Fruiting laterals:			
Length	Variable, but majority of long hanging type comparable with Fuggle.	Majority somewhat shorter than average Fuggle. A small proportion of long hanging ones comparable with Fuggle.	Variab of m in F
Disposition on bine	Produced well down on bine.	Produced well down on bine.	Produ
Cones:			
Disposition on laterals	Clusters close together on short laterals much more widely spaced on long laterals	Clusters close together on short laterals, much more widely spaced on long laterals.	Cluste wide
Size	Moderate. Usually smaller than Fuggle but sometimes comparable with it.	Moderate. Usually smaller than Fuggle but sometimes comparable with it.	Compa bold
Shape	Square in transverse section ; of medium length gently tapering to rounded tip, i.e. proportions as Fuggle but due to smaller size appear ' dumpy '.	Rectangular in transverse section giving characteristically 'flat' appearance; length often over twice widest elevation giving rather elongated appearance.	Very si
Density	Moderately tight and definitely much more so than Fuggle.	Generally loose and more open than Fuggle.	Genera
Colour	Of medium deep colour when ripe with slight striping effect, corners (bracts) being darker than faces (bracteoles).	Pale when ripe. Narrow faces (bracts) slightly darker than broad faces (bracteoles).	Good c very corn (bra
Appearance	Neat and compact.	' Ragged ' when viewed on broad face.	Very s
Hop/Bine and Leaf ratio†	Medium to low.	Medium.	High.
Sprig thickness	Slightly less than Fuggle.	Similar to Fuggle.	Slightl
General	Shows a strong ' family ' resemblance to OR55.		

* Generally determined at harvest time.

† This ratio is of significance as indicating ' harvesting properties ', particularly in relation to machine harvest to bine and leaf would be expected to be more suitable for machine picking than others.

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Variety	L
Density (D1)	Ca
	F1
	M
Defender (D3)	B
	F
Janus (J2)	B
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Summary

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small, are

y susceptible to downy mildew and requires a thorough control programme. In brewing trials it has been found suitable for replacing 25 and 50 per cent of normal grist, and received some favourable reports when used alone.

Defender (D3) is an early hop of vigorous growth habit and good yield potential. It is of above-average susceptibility to downy mildew and requires a thorough control programme. In brewing trials it has been found suitable for replacing 25 and 50 per cent of normal grist and received some favourable reports when used alone.

Janus (J2) is a mid-season hop of moderate growth vigour and yield potential. The cones are bold and borne in a manner likely to suit machine picking. It is of average susceptibility to downy mildew and should require only normal control measures. In brewing trials it was acceptable as a substitute for normal grist at 25, 50 and 100 per cent replacement, and resin analyses suggest that such substitution may be made on a weight-for-weight basis.

All three varieties are tolerant carriers of hop mosaic virus.

References

1) Keyworth, W. G., Hitchcock, Margaret M., and Goode, Pamela M. (1953). *Verticillium* wilt of the hop. VII. Further studies on wilt-resistant varieties. *Rep. E. Malling Res. Sta. for 1952*, 112-19.

2) Salmon, E. S. (1949). Two new hops resistant to *Verticillium* wilt. *Wye College, Kent.*

3) Harris, R. V. (1954). Wilt-tolerant hops. *Rep. E. Malling Res. Sta. for 1953*, 208-9.

4) Talboys, P. W., and Wilson, J. F. (1954). A method for determining the pathogenicity of strains of *Verticillium albo-atrum* isolated from the hop. *Rep. E. Malling Res. Sta. for 1953*, 158-61.

5) Hops Advisory Committee : Institute of Brewing (1954) (1955) (1956) (1957) (1958). Institute of Brewing Hop Trials 1952 Crop—1956 Crop. *J. Inst. Brew.* 1954, 414-19 ; 1955, 372-76 ; 1956, 304-8 ; 1957, 312-15 ; 1958, 388-91.

6) Wilson, J. F. (1957). Whitbread's Golding Variety Hop : A note on wilt tolerance in the field and the establishment of a *Verticillium*-free planting stock. *Rep. E. Malling Res. Sta. for 1956*, 128-30.

A MILD STRAIN OF HOP MOSAIC VIRUS

By J. T. LEGG

Salmon (1923) described hop mosaic as a lethal disease, but Mackenzie *et al.* (1929) showed that only Golding types of hop and some male varieties were killed, other varieties being mosaic tolerant and carriers. In recent years, however, plants of sensitive varieties have been found showing mosaic symptoms but with only slightly impaired vigour. Since 1952, such plants have been recorded on eleven farms in the South East and West Midland areas of England. The varieties affected were Cobbs, Tutshams, Bramling, Early Bird, and Eastwell Golding. The leaf symptoms of the two types of mosaic are not sufficiently distinct for diagnosis but they can be clearly distinguished by the fact that one type causes mortality to sensitive varieties ; in no instance has a Golding hop been killed by a virus transmitted from a mildly affected plant. Thus there are two syndromes, the mild which is non-lethal and the severe which includes, among other symptoms, the rapid death of sensitive hop plants. The possibility of a strain relationship between the viruses responsible for the mild and the severe effects was tested in the experiments described below, using a mild isolate with the least effect on vigour and a severe isolate from the variety Fuggle N (mosaic carrier).

Mosaic symptoms of sensitive varieties

Severe mosaic

The diagnostic features of severe mosaic are cholorotic vein banding on young leaves, and an indistinct mottle and marked recurving of leaf margins of older leaves (Fig. 1). The stems fail to twine and the internodes are short. Only a few flowers are formed and these give rise to misshapen cones (Fig. 3). Affected plants are killed within two years.

Mild mosaic

Mild mosaic is not lethal and symptoms do not occur on young leaves until they have fully expanded, when a distinct light green or yellow mottle develops (Fig. 2). Stems continue to climb on the supporting strings and although internodes are not shortened, vigour is impaired possibly because growth stops earlier than with healthy plants. Flowers are produced normally but the hop cones are small and loosely formed (Fig. 3).

Cross-protection tests

The ability of a virus to protect its host from the effects of a second challenging virus is regarded as evidence that the two viruses are closely related. Although not infallible, cross-protection tests have generally given results in agreement with serological tests when the latter have been applied.

Two cross-protection tests with hop mosaic viruses were made by inoculating the severe isolate into shoots of the sensitive variety Cobbs. Nine scions from a healthy plant and seven from a plant with symptoms of mild mosaic were each top-grafted onto separate Fuggle rootstocks (carrier of severe mosaic). Five of the healthy scions did not unite, a typical reaction of sensitive scions top-grafted on to a rootstock infected with severe mosaic (Thrupp, 1927). The remaining four made restricted growth (1-4 ft) and developed typical symptoms of severe mosaic. The seven scions infected with the mild isolate all united with the Fuggle and with one exception all made good extension growth (5-13 ft) showing mild mosaic symptoms. One plant although only three feet tall continued to climb, and the internodes were of normal length.

In the second test the severe mosaic isolate was inoculated from either a mosaic sensitive or tolerant variety into Cobbs plants growing on their own roots and showing mild mosaic symptoms. Five plants were graft-inoculated with each of the two severe mosaic sources ; the ten Cobbs plants continued to make normal extension growth (9-13 ft) and showed only symptoms of mild mosaic. During the same period ten healthy Cobbs plants inoculated from the same sources of severe mosaic all developed typical severe mosaic symptoms, none growing more than one foot tall.

Discussion

The two types of mosaic used in these tests have shown consistent differences in their symptoms. Furthermore, in two cross-protection tests the presence of the mild isolate appears to have suppressed the symptoms of the severe isolate, thus indicating that they are strains of the same virus.

Fig. 2
Mottled leaf from a plant infected with a mild strain of mosaic

Fig. 1
Distorted leaf from a plant infected with a severe strain of mosaic

FIG. 3

Laterals showing cone development: *right*, from a healthy plant, *centre*, from a plant infected with a mild strain, and *left*, from a plant infected with a severe strain of mosaic

The diseases caused by these two isolates represent the extremes of a range of mosaic symptoms, and this suggests that there are many different strains of the virus (*Humulus* virus 1, Smith). The symptoms of different mild isolates are too similar for the interpretation of tests for cross-protection, and lethal isolates are unsuitable for such tests because they kill the plants too rapidly. It seems advisable, therefore, to assume provisionally that there are two groups of strains, mild and severe, the latter group containing those isolates that are lethal to sensitive varieties.

On this basis the hop mosaic diseases described from Czechoslovakia (Blattný and Osvald 1949) could be classified : ornamental mosaic, false ornamental mosaic, speckled mosaic, and yellow spotted mosaic, in the mild group and variegated mosaic in the severe group. It now seems probable that chlorotic mosaic disease reported by Cairaschi (1953) from the Alsace region of France should be included in the mild mosaic group and considered distinct from chlorotic disease (*Humulus* virus 3, Smith).

Acknowledgement

The author wishes to acknowledge the original observations of Mr. J. Paine which led to this investigation.

Summary

Evidence from cross-protection tests indicates that two types of hop mosaic, lethal and mild, are caused by strains of one virus (*Humulus* virus 1, Smith). It is suggested that these two isolates are representatives of two groups of strains, severe and mild, distinguished by the former being lethal to Golding hops.

References

Blattný, C., and Osvald, C. V. (1949). Předběžný přehled viros Chmele a boj proti nim. *Ochr. Rost.*, **22**, 5-28.

Cairaschi, E. A. (1953). Note sur la ' mosaïque chlorotique ' nouvelle maladie à virus des Houblons en Alsace. *Rev. Path. vég.*, **32**, 175-80.

Mackenzie, D., Salmon, E. S., Ware, W. M., and Williams, R (1929). The mosaic disease of the hop ; Grafting experiments, II. *Ann. appl. Biol.*, **16**, 359-81.

Salmon, E. S. (1923). The ' mosaic ' disease of the hop. *J. Minist. Agric.*, **29**, 927-34.

Thrupp, T. C. (1927). The transmission of ' mosaic ' disease in hops by means of grafting. *Ann. appl. Biol.*, **14**, 175-80.

ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1958

By A. M. MASSEE

1. Large fruit bark beetle (*Scolytus mali* Bht.)

The large fruit bark beetle, a species of wood-boring beetle associated with apple, plum and apricot, is locally common throughout Kent.

This beetle caused considerable damage to a cherry orchard near Rochester, Kent. Normally the beetle bores into the shoots, branches and trunks of the trees, but at Rochester the damage was unusual ; the beetles were observed boring at the base of the buds on the new growth of the variety Roundel Heart. Many buds were attacked in this manner, causing them to shrivel and dry out. Similar damage was seen the year previously.

Many of the trees in adjoining apple and plum orchards were badly infested with the beetle, and it probably spread from these trees to the cherry orchard.

2. Apple fruit moth (*Argyresthia conjugella* Zell.)

The apple fruit moth has been known as a minor pest for many years near Canterbury, but seemed to be confined to that area. In recent years it has been extending its range and it is now well-established at East Peckham and West Farleigh in Kent, and at Hindhead, Surrey and Fernhurst, Sussex.

At West Farleigh the first instar larvae were found in the fruitlets of Tower of Glamis apple on 15th May, and they were plentiful in June. More young larvae were found in September, suggesting that there may be two broods in some seasons.

Although the outbreaks at East Peckham and West Farleigh are becoming more severe, the infestations noted at Harbledown, Nr. Canterbury, for many years still remain low.

3. Cherry-bark tortrix (*Ernarmonia formosana* Scop.)

The cherry-bark tortrix has been familiar to most Kentish cherry growers for many years. The larva makes galleries just under the bark of the trunk, and usually attacks established trees of twenty years or more.

Recently this tortrix has become more numerous and its host range has extended so that today it is common on apple in addition to cherry. It is common in some apple orchards at Horsmonden and Paddock Wood where damage has been caused to Newton Wonder. Larvae collected at Paddock Wood last winter proved to be this species, and adults were bred in the laboratory by the middle of March.

This insect has been known also in the Wisbech district for many years, but has become more common in recent seasons, and it is regarded as an important pest in some orchards. The dull pinkish-white or dark-brown larvae feed just under the bark, forming irregular, shallow tunnels. The same tunnels are used each year by successive generations—thus after some years deep channels are formed which may be 2 in. or more wide.

The larvae of the apple clearwing moth often occur in the tunnels made by tortrix larvae, so that frequently the two species confuse the grower. The caterpillar of the apple clearwing is a dull yellowish-white, with a brown head, and attains a length of about $\frac{1}{2}$ in. when mature, whereas the tortrix larva is a dull pinkish-brown or dark brown, about 1 in. long when mature, and it wriggles backwards when touched. The two species therefore are readily recognized.

The cherry-bark tortrix is on the wing from May until September or even later, and there are two generations each year.

A detailed study of the life history and control measures has not been made, but the pest can be kept in check by scraping the tree trunks in early winter to remove loose bark and applying a tar oil winter wash. Some growers prefer to omit the winter treatment and spray the trunks of the trees with DDT emulsion about the middle of May ; this treatment proved very effective at Paddock Wood last season.

Mr. J. H. Stapley, Plant Protection Ltd. has bred cherry-bark tortrix moths from larvae collected from under the bark of old apple trees. In addition he bred out a species called *Esperia sulphurella*

(Fab.) from larvae found in similar situations. The latter record is of interest since the same species was bred from larvae found under old apple bark some twenty years ago at East Malling, but has not been recorded since that time.

4. Bramble shoot moth (*Notocelia uddmanniana* L.)

The bramble shoot moth or bramble shoot webber, a common pest of cultivated blackberry and loganberry twenty years ago, has been much less prevalent in Kent in recent years.

In May it was common on cultivated blackberry and on Malling Promise raspberry in a plantation at Faversham and another at Teynham, Kent. In both fields the infestation was equally severe on raspberry and blackberry. In both cases the raspberry fields were next to the blackberry from which the insect appeared to have spread. The normal hosts of this insect are blackberry, loganberry and phenomenal berry ; its occurrence on raspberry is a new host record.

The bramble shoot moth frequently causes considerable harm to the canes of blackberry by the larvae bunching together the leaves towards the tips of the canes, frequently destroying the growing tip and causing lateral growths to develop and produce malformed canes.

5. Winter moth (*Operophtera brumata* L.)

Until two seasons ago the winter moth population was small, probably because of the introduction of DDT and BHC into the pre-blossom spray programme in 1948.

Last season, however, there was a noticeable increase in populations of winter moths in many orchards in mid-Kent. This spring the populations increased still further, and in some orchards considerable damage was caused by the larvae feeding on the foliage. The true explanation for this gradual increase in winter moth populations is not known, and it occurs in orchards where different spray programmes are used, and where the method of application varies considerably. In most orchards DDT or BHC or a combination of the two are still applied pre-blossom and the winter moth populations still persist.

It is interesting that the caterpillars of the March moth and mottled umber moth have also been more plentiful during the past two seasons.

6. Codling moth (*Ernarmonia pomonella* L.)

The percentage of codling-infested fruit varies in different apple and pear orchards each season, being highest when populations of the moth reach a peak. In peak years much fruit may be downgraded as a result of infestation. The present year has largely followed the same pattern as the two previous ones, but once again the populations are reaching a peak period. The infestation proved negligible in June and July, but by the middle of August codling-infested fruits were plentiful. Bad infestations on apple and pear have been noted in mid-Kent, and some orchards near Malling have had a heavy attack of codling. The infestation tends to increase during late August and September, and young larvae have been found in fruits just prior to harvest. These late infestations are particularly troublesome, since the use of chemicals is ruled out, and there seems to be no means of protecting the fruits against attack.

For many years, pears have not suffered to the same extent as apple, but many pear plantations near Maidstone have suffered severely this year. Conference appears to be the variety mainly affected.

Several larvae noted in the fruits of walnut at East Malling proved to be this species.

7. Apple sawfly (*Hoplocampa testudinea* Klug)

Among the common pests that occur in commercial apple orchards, the apple sawfly is regarded as one of the most regular in its appearance, especially where Worcester Pearmain, Cox's Orange Pippin, Laxton's Superb, James Grieve and Beauty of Bath are grown. This season proved an exception, however, for in many orchards in widely different parts of Kent where sawfly usually abounds, populations were small or absent.

The explanation for this phenomenon is not known. It has been established that a small proportion of the over-wintering pupae remain in the soil for a second year, and it may well be that a greater proportion of pupae failed to emerge in May than is usual.

In one orchard at Plaxtol, Kent, large numbers of apple sawfly were observed, but this was exceptional for the year 1958.

8. Apple-grass aphid (*Rhopalosiphum insertum* Wlk.)

The apple-grass aphid or the oat-apple aphid (a name familiar to most fruit growers) annually causes a good deal of concern to the orchardist in April and May because the aphid is capable of rapidly

building up large populations causing much harm to the trees. The tendency for the aphid to build up large populations usually occurs in orchards where the winter wash has been omitted and the grower relies upon pre-blossom applications of DDT or BHC, or a combination of the two.

The year 1957 proved to be a bad year and many growers were wondering what might happen the following season. In most parts of Kent, however, populations of the apple-grass aphid were low, and one or at most two sprays usually provided adequate control.

An exception was noted at Leeds, Kent, where a Bramley's Seedling orchard was very severely infested, necessitating three pre-blossom sprays, and even then the aphid persisted in small numbers until after petal-fall.

9. Pear sucker (*Psylla pyricola* Föer.)

Although the pear sucker has been a troublesome pest for many years in Kent and Surrey it has been more prevalent this year than usual.

Abnormally high populations were noted at Faversham, Rainham, mid- and north Kent in April and May. Reports from East Anglia indicate that it is now well established in Suffolk, and in Essex, two severe infestations were noticed at Writtle on Conference pear.

The overwintering adults started egg laying early in March in the Malling district, and observations made at East Malling verified that third generation adults were found by the middle of August, and it is considered that a partial fourth generation occurred in late September. This was exceptional since in most seasons the insect has only three generations.

The pear sucker is a difficult insect to study under field conditions because it does not necessarily remain in the same plantation throughout the year. Population records indicate that the insect may be common in April and May, and when the adults of the first generation occur, it often migrates elsewhere. Later in the year the same trees may become re-infested and in due course eggs are laid on the shoots and leaves. In these circumstances it is not easy to predict just how serious pear sucker is likely to be in any given orchard.

Summary

Brief accounts are given of some interesting insects observed in 1958. Some of the more important are the large fruit bark beetle, the apple fruit miner, the cherry-bark tortrix, the bramble shoot moth and the pear sucker.

METHODS FOR ASSESSING RESISTANCE TO *AMPHOROPHORA RUBI* (KALT.) IN THE RASPBERRY

By J. B. BRIGGS

Various authors have reported resistance to *Amphorophora rubi* (Kalt.) in the raspberry. Lloyd George being particularly resistant in North America (8) though not in Europe (2), while Malling Landmark is resistant in Europe (7, 4) though not in North America (3). Knight, Keep and Briggs (6) described plant breeding work at East Malling designed to investigate the genetics of the resistance of Landmark, and to transfer it to commercially acceptable raspberry varieties. The present paper describes and discusses the entomological methods devised for three main aspects of this work, viz., locating strong sources of resistance, testing the distribution of resistance in young seedling progenies derived from resistant parents, and checking the accuracy of the seedling test by subsequent field observation.

Methods for locating strong sources of resistance

In an insectary survey for resistance, many potted raspberry varieties and un-named seedling selections were repeatedly mass-inoculated with aphids of a strain described by the author (1) as *Amphorophora rubi* European raspberry strain 1, from stocks reared on plants known to be susceptible. In these tests, strong resistance implied virtual immunity under the conditions of the test; weak resistance implied that comparatively small numbers of aphids colonized the plants, the aphids often being undersized and feeding, even early in the season, only on mature or senescent leaves, instead of predominantly on tip leaves: susceptibility implied that the aphids colonized the plants and commenced to breed, normally at the first inoculation. Many varieties were shown to be susceptible between 1952 and 1957, but strong resistance was found in the discarded variety Baumforth A, and some of its derivatives, including Landmark, and the un-named selection 64/2, and also in the American commercial variety Chief and in some of its derivatives, including the selection 87/6 (6). These tests were repeated four times on Landmark and six times on 87/6, with the same result, between 1952 and 1957. Weak resistance was noted in Baumforth B, Hercules, Latham, Norfolk Giant, Royal Scot, and in certain selections, including 86/69 and 87/76. Hill (4) reported resistance in Landmark and weak resistance in Latham and perhaps in Norfolk Giant, but Newburgh, which Hill considered somewhat resistant, was susceptible at East Malling.

Further confirmation of the resistance of Baumforth A, Landmark, and 87/6, and the weaker resistance of 86/69 and 87/76 was obtained in an experiment in 1955, when these varieties were compared with plants of a fully susceptible selfed down line P1 (6). Vigorous, uniform, potted plants of these varieties were set out in an insectary, on inverted pots standing in trays of water, so that movement of apterous aphids from plant to plant was minimized. There were six replicates of all varieties, which were arranged within each replicate in random order, and inoculated on 20th July with ten apterae. A fortnight later, all aphids present were counted (Table I).

TABLE I

MEAN POPULATION OF APHIDS ON SIX PLANTS OF SIX RASPBERRY VARIETIES FOURTEEN DAYS AFTER INOCULATION

Variety	Mean number of aphids	S/E
Landmark	0·2	0·15
Baumforth A ..	0·2	0·15
87/6	0	0
86/69	4·5	2·5
87/76	24·5	12·2
P1	108·8	12·9

Methods for testing seedlings for transference of resistance

The techniques used in the plant breeding programme at East Malling have been described elsewhere (6). To obtain an accurate assessment of the number of resistance genes involved, fairly large numbers of plants had to be tested. Because space was limited, and seedlings had to be planted

in the field as early in the season as possible, it was decided to give them a rapid test, followed by frequent inspections in the field, when any errors in the insectary classification would become apparent. In each year from 1955-7, therefore, the seedlings, in 3-in. pots, were transferred to the insectary after being dipped in a non-persistent aphicide or examined very thoroughly to ensure freedom from aphids, and lined out on inverted pots in trays of water on benches. One adult aptera was transferred to the first open leaf of each from a stock plant or from a seedling whose test was finished. If the aphid did not settle and feed, but left the plant, another aphid was transferred ; if this again failed, a third aphid was transferred, except in 1955, when due to unexpected mortality among the hatching eggs, a shortage of aphids often made a third inoculation impossible. If three inoculations failed, the plant was classified as resistant. If nymphs were deposited, the plants were examined daily, until the nymphs died, left the plant, or matured to the fourth instar winged nymph or adult apterous stage. If any nymphs matured, the plants were graded as susceptible, though the normal criterion of susceptibility was ability to carry five or more nymphs to maturity.

Methods for checking the insectary forecast in the field

The numbers of plants involved made it impossible to count aphid populations on entire plants, as a field check of the insectary forecast of resistance. The seedlings were too young to propagate and, being of hybrid origin, differed widely from one another in habit and vigour. The problem, therefore, was to devise a sampling method for comparing aphid infestations on dis-similar plants, under conditions in which no replication of the plants was possible. To provide basic information on the variation in aphid population from leaf to leaf and from cane to cane counts were made in 1956 on sample leaves from the current years' cane of seven varieties differing widely in vigour, habit, and parentage. The varieties were Malling Promise, Malling Exploit, Norfolk Giant, 64/2, 64/53, 69/105, and 72/59. The sample was made up as follows :

The opening young leaf of the type which previous experience suggested was likely to be the most heavily infested;
The leaf immediately below this leaf ;
A mature leaf selected at random ;
The leaf immediately below this mature leaf.

Four such leaves were taken from a total of 16 canes, made up as follows :

2 canes selected at random from each of
4 stools, again selected at random from each of
2 plots of each of the seven varieties available.

Only on 15th June and 3rd July were aphids abundant enough to be worth counting, when the mean number of aphids per leaf for all leaves from all seven varieties was 0·72 and 0·80 respectively ; these counts are summarized in Table II, where the standard deviations shown are those of the mean numbers of aphids per leaf, for the replications of each factor, from the grand mean for all leaves on each occasion, 0·72 and 0·80 aphids per leaf respectively. There was little variation from plot to plot, larger variation between stools and canes, and greatest variation between leaf positions and varieties. This information was now applied to the problem of devising a sampling method for single plants and the following conclusions were reached. Inability to take samples from more than one stool or plot would not lead to great errors in assessing infestations, since the variation due to these factors was relatively small, but sample leaves should be drawn from as many canes as possible to reduce the error due to cane-to-cane variation. The choice of the position on the cane from which sample leaves should be taken was highly critical, the variation between populations on the selected young leaf and its neighbour being so great that random selection among the younger leaves could give misleading results.

Further work in 1957 was directed towards finding, in a number of dis-similar varieties, that leaf type which had the highest infestation, and would therefore give rise to the least error if used for sampling infestations on seedlings. This was again done on a range of dis-similar varieties, five in number, consisting of Promise, Exploit, Norfolk Giant, 64/2 and 64/53. The aphids on every leaf of 20 randomly selected current season canes of each of these varieties were counted on 7th and 27th May and 16th June. Before and after these times aphids were not abundant enough for counting to be worth while. At the same time the leaves were graded as follows : tip ; leaflets unfolding ; first leaf with flat leaflets ; other leaves with flat leaflets ; leaves with more than one-tenth of their area yellowing or brown. The use of terms such as mature and senescent, used by Kennedy, Ibbotson and Booth (5) in their work on the leaf preference of aphids, has been avoided, as full maturity in the raspberry leaf is very difficult to judge.

Table III shows details of these counts for each variety and sampling occasion. On the first occasion, on the varieties Promise, Exploit, and 64/53, most aphids were on the tip, unfolding and

Table II

Mean number of aphids per leaf, for various factors

Factor	Replicate number	Number of leaves	15th June 1956		3rd July 1956	
			Mean no. of aphids per leaf	Standard deviation	Mean no. of aphids per leaf	Standard deviation
Plot	I	224	0·67	0·045	0·82	0·049
	II	224	0·76		0·77	
Stool	I	112	0·51	0·162	0·83	0·234
	II	112	0·79		0·90	
	III	112	0·63		0·86	
	IV	112	0·94		0·60	
Cane	I	224	0·90	0·179	0·61	0·185
	II	224	0·54		0·98	
Leaf position	Young leaf	112	0·54	0·502	0·54	0·331
	Next below	112	1·68		1·32	
	Mature leaf	112	0·32		0·49	
	Next below	112	0·33		0·84	
Variety	Promise	64	1·76	0·540	1·20	0·593
	Exploit	64	1·09		0·75	
	69/105	64	1·12		1·89	
	64/53	64	0·72		0·59	
	72/59	64	0·31		0·94	
	Norfolk Giant	64	0·02		0·16	
	64/2	64	0		0	

Table III

Mean number of aphids per leaf, and percentage of total aphids, for each leaf category, in five raspberry varieties

Date	Variety	Total aphids on 20 canes	Mean number of aphids per leaf for each category					Percentage of aphids on leaves of each category				
			Tip	Unfolding leaves	First flat leaf	Other flat leaves	Yellowing leaves	Tip	Unfolding leaves	First flat leaf	Other flat leaves	Yellowing leaves
7th May	Exploit	109	0·1	2·8	2·9	0·1	—	2	28	59	1	—
	Promise	69	0	2·1	1·6	0·1	—	0	28	66	7	—
	Norfolk Giant	10	0	0	0	0·1	—	0	0	0	100	—
	64/53	91	0·1	3·3	2·1	0·3	—	1	25	40	34	—
	64/2	0	0	0	0	0	—	0	0	0	0	—
27th May	Exploit	506	0·3	4·8	7·4	1·1	3·6	1	17	31	39	12
	Promise	332	0·2	1·0	5·9	1·0	2·3	1	4	35	52	7
	Norfolk Giant	51	0	0	0	0·3	0	0	0	0	100	0
	64/53	171	0	1·4	3·1	0·7	0	0	11	36	53	0
	64/2	0	0	0	0	0	0	0	0	0	0	0
16th June	Exploit	443	0·1	0·3	1·9	1·7	2·5	0	1	8	81	9
	Promise	212	0·1	0·1	0·5	0·9	1·1	1	0	4	83	11
	Norfolk Giant	192	0	0·1	0·6	0·7	3·5	0	1	6	83	11
	64/53	195	0	0·7	0·6	1·0	1·7	0	3	6	89	3
	64/2	16	0·1	0	0·2	0·1	2·0	6	0	19	63	12

first flat leaves (66 to 99 per cent according to variety). On Norfolk Giant, only ten aphids were seen and these were all on the older leaves. No aphids were found on the resistant variety 64/2. On the second occasion, larger numbers of aphids were present, and on Promise, Exploit and 64/53 there were still many on the tip, unfolding and first flat leaves, though a lower proportion than before (40-49 per cent according to variety). Aphids had begun to appear on the yellowing leaves. Fifty-one aphids were found on Norfolk Giant, but once again none were on the younger leaves. Again no aphids were found on 64/2. On the third occasion the drift of the aphids from the younger categories of leaves had continued in Promise, Exploit and 64/53, so that although the total numbers of aphids were roughly comparable with the last sample, the mean number of aphids per tip, unfolding and first flat leaf had fallen sharply and only 5-9 per cent of the total aphids, according to variety, were to be found on these leaf types. A compensating rise in the mean number and percentage of aphids on the leaves of the older categories had taken place. There were now 192 aphids on the twenty canes of Norfolk Giant, and once again they were predominantly on the leaves in the older categories. This, of course, was now in line with the other varieties. 64/2 now had 16 aphids present, all of which except one were on the older leaves.

While this work was in progress, counts were also made on the seedlings planted between 1955 and 1957. One young leaf was taken from near the tip of each spawn growth; selection was not critical until 1956, when, using the information obtained from the work already described, the first flat leaf was deliberately selected for sampling. A check on the validity of this sampling procedure, was made in early September 1956 by counting the aphids on all the leaves of one current season's cane, of 102 seedlings, that had been planted in random pairs, one of each pair having been graded resistant and one susceptible in the insectary. The results were compared with those from the last leaf sample made in July and there was good agreement, the correlation coefficient between the mean number of aphids present per ' first flat ' leaf in July, and the aphids present on one cane in September being 0·2255, significant at the one in twenty level and only just failing to achieve significance at the one in fifty level. There was also good agreement between sample counts made on different occasions.

So far no account had been taken of the aphids present on the fruiting cane in the first half of the season, and, to ensure that results from fruiting cane agreed with those from young cane, counts were made in mid-April 1957, on the same seedlings, of the aphids present on all leaves of the fruiting laterals developing from one cane, and on all leaves of one spawn growth from the same plant. Ninety plants were available with both types of growth. Agreement between the two counts was good, the correlation coefficient between the total aphids present on the canes of each sort being 0·2882, which was significant at the one in one hundred level.

Discussion

Locating sources of resistance.—Clearly resistance to a particular stock of aphids can be demonstrated in a number of ways : by repeated mass inoculations, by replicated tests such as those described by the author where a free choice is given to the aphids to walk off if the plant is distasteful, or by caging aphids on the plants and using criteria such as the fecundity and longevity of individual aphids to assess degrees of resistance (4). But the discovery of strains of aphids capable of reproduction on certain plants resistant to other strains (1) shows that such tests, however exhaustive, cannot replace field observation in the assessment of field resistance.

Testing seedlings for resistance in the insectary.—Most normal plants gave clear-cut results, in that the aphids used for three successive inoculations left the resistant plants, leaving no progeny, or that five or more nymphs matured successfully in the case of susceptible plants. Plants belonging to groups with some abnormality often gave differing results. One such group comprised plants of the genotype ' frilly ' (6) ; plants of this type are slow growing and deficient in lamina tissue. Another group, derived from weakly resistant parents, often the variety Norfolk Giant, comprised plants where the aphids, when established, only fed on the stems and lower leaves and not at the tip as is characteristic. The last group consisted of plants which had become seriously potbound, during an attempt to test them with more than one strain of aphids, over a period of five or six weeks. Many of these could be shown by repeated inoculation to be susceptible, although the first three aphids had left the plants. Table IV illustrates the differences between normal plants, and the plants belonging to the abnormal groups. Here, all plants graded susceptible between 1955 and 1957 are placed in groups according to the inoculation to which they had succumbed. In normal plants most succumbed to the first, and the number of successes at the second and third inoculation fell so sharply as to suggest that a very small number of undetected susceptibles remained after the third inoculation. With the ' abnormal ' groups there is no such tailing off, there are probably many undetected susceptibles, and repeated inoculation is necessary to establish the last few susceptibles in groups like these. This method of examining the data gave a good indication of the accuracy of the insectary forecast before field results were available for comparison.

TABLE IV

PERCENTAGES OF PLANTS COLONIZED BY SUCCESSIVE INOCULATIONS WITH *AMPHOROPHORA RUBI*

Type of plant	Total number of plants	Percentage colonized at each inoculation			
		1st	2nd	3rd	Others when made
Normal	612	80	16	4	—
Frilly	130	28	22	22	28
Atypical plants. Parents weakly resistant ..	202	40	36	23	1
Potbound	308	50	23	21	6

Plants deriving resistance from 87/6 have become uniformly infested in the field due to the presence there of a strain of aphids capable of colonizing these plants, but plants deriving resistance from the Baumforth A source showed almost without exception, the resistance in the field that was forecast in the insectary.

Field counts.—Several points emerged from the field counts. First, the maximum density of aphids on the varieties Promise, Exploit, and 64/53 was shown, in the first count made in 1957, to be on the first flat leaf. The sample of twenty such leaves, one from each cane, gave an excellent index of the relative levels of infestation of 20 canes of these three varieties, the mean value for the leaves being almost the same proportion of the total for each variety. Agreement between the sample and the total was less good on 21st May however, and worse still on the 16th June. Second, the young leaves were not preferred at any time by the aphids in the case of Norfolk Giant. Non-preference of the young leaves of Norfolk Giant and its progeny had also been observed in the insectary, the aphids being small in size compared with normal colonies at the tips on other varieties. Third, 64/2 was never more than lightly infested, and this would have been apparent if even a small number of leaves had been taken as a sample. Since the high degree of correlation between the young cane and fruiting cane counts showed that the fruiting cane could be safely ignored, the following recommendations can be made for sampling populations on seedlings. First, a sample of ' first flat ' leaves early in the season should give almost as good results as a sample of canes, on all but atypical seedlings resembling Norfolk Giant. Secondly, using such leaves, accuracy will decline as the season advances and, as aphid numbers will also drop, it is advisable to make counts early in the season. The exact period cannot be defined by date but will probably coincide with the period of vigorous growth of the young cane.

General.—The methods evolved for testing in the present investigation have so far been very successful, and it has already been possible to obtain a clear understanding of the genetics of resistance derived from Baumforth A (6). That results are so encouraging is doubtless due to the strong nature of the resistance concerned. It is significant that both insectary and field results with the weakly resistant Norfolk Giant and its progeny present a complex picture. There seems little doubt that breeding for resistance from a strong source is likely to lead to faster progress than attempting to assemble in one plant a number of factors for resistance of small individual effect, as the methods used in the former case can be very much simpler.

Summary

Techniques for forecasting resistance to *Amphorophora rubi* (Kalt.) in raspberry varieties and seedlings, in the insectary, and for comparing infestations on individual seedlings in the field, are described and discussed. Mass inoculation is used to locate resistance in potted varieties and selections in the insectary. A simple test for seedlings, using three inoculations of a single aphid, gave a very accurate forecast of resistance derived from Baumforth A, judged by subsequent field observation at East Malling. The use of leaf samples to estimate relative degrees of infestation in the field was examined and found adequate to check the resistance of Baumforth A derivatives in the field during the early part of the season. Unusual behaviour of the aphids on the variety Norfolk Giant is reported.

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References

(1) Briggs, J. B. (1959). Three new strains of *Amphorophora rubi* (Kalt.) on cultivated raspberries in England. *Bull. ent. Res.* (in the press).
(2) Dicker, G. H. L. (1940). The biology of the *Rubus* aphides. *J. Pomol.*, **18**, 1-33.
(3) Hill, A. R. (1956). Observations on the North American form of *Amphorophora rubi* (Kalt.) (Homoptera, Aphididae). *Canad. Ent.*, **88**, 89-91.
(4) ——— (1957). Observations on the reproductive behaviour of *Amphorophora rubi* (Kalt.) with special reference to the phenomenon of insect resistance in raspberries. *Bull. ent. Res.*, **48**, 467-76.
(5) Kennedy, J. S., Ibbotson, A., and Booth, C. O. (1950). The distribution of aphid infestation in relation to leaf age. I. *Myzus persicae* (Sulz.) and *Aphis fabae* Scop. on spindle trees and sugar beet plants. *Ann. appl. Biol.*, **37**, 651-79
(6) Knight, R. L., Keep, E., and Briggs, J. B. (1958). Genetics of resistance to *Amphorophora rubi* (Kalt.) in the raspberry. I. The gene A_1 from Baumforth A. *J. Genet.*, (in the press).
(7) Knonenberg, H. G., and de Fluiter, H. J. (1951). Resistentie van frambozen tegen de grote frambozenluis *Amphorophora rubi* (Kalt.). *Tijdschr. PlZiekt.*, **57**, 114-23.
(8) Schwartze, C. D., and Huber, G. A. (1937). Aphis resistance in breeding mosaic-escaping red raspberries. *Science*, **86**, 158-9.

A PRELIMINARY STUDY OF THE TOXICITY OF LIME-SULPHUR AND OTHER FUNGICIDES TO *PSALLUS AMBIGUUS* (FALL.) (HEMIPTERA-HETEROPTERA: MIRIDAE)

By W. REED*

The mirid, *Psallus ambiguus* (Fall.), although common in unsprayed orchards in south-east England, is usually absent from those receiving a full spray programme. Since this insect is an important predator of the fruit tree red spider mite, *Metatetranychus ulmi* (Koch) (1), and perhaps of other pest species, its absence assumes considerable importance when consideration is given to the potentialities of utilizing natural enemies to control apple pests. Whilst it is generally assumed that the use of insecticides prevents the establishment of *P. ambiguus* in such orchards, there is evidence to indicate that the fungicide, lime-sulphur, is toxic to certain insects (4) and may depress populations of beneficial arthropods (2). As lime-sulphur is applied at intervals throughout the period when nymphal stages are present, the following study was made to determine the toxicity of this and other fungicides in general use.

Materials and methods

Second or third instar nymphs, collected from unsprayed apple trees, were used in all tests. As this species is predacious, living specimens of the aphid, *Aulacorthum circumflexum* (Buckt.), from a laboratory culture were provided as food. During tests the insects were placed in 3 × 1 in. glass specimen tubes, the bottom of each tube being lined with a small wad of cotton wool moistened with 1 ml. of distilled water which was covered by a disc of filter paper. Because of their strong cannibalistic habits under crowded conditions only three or four nymphs were placed in each tube. All tests were conducted at a constant temperature of 72° F.

The three fungicides studied were :

lime-sulphur—a solution containing 24 per cent (w/v) polysulphide sulphur,
dispersible sulphur—containing approximately 70 per cent (w/w) sulphur,
captan—N-trichloromethylthio*cyclo*hex-4-ene-1 : 2-dicarboxyimide. A 50 per cent wettable powder was used.

The toxicity of various fungicides

Apple leaves, after being dipped in solutions or water suspensions of the materials listed in Table I, were allowed to dry for three hours, then placed singly in tubes to which three nymphs of *P. ambiguus* and some aphids were added. To obtain the maximum effect of any fumigant action which might occur the tubes were tightly corked. Each treatment was replicated five or ten times.

TABLE I

THE TOXICITY OF FUNGICIDE DEPOSITS TO *P. AMBIGUUS*

Treatment	No. of insects	No. dead after 24 hr	Percentage mortality
1·25 per cent lime-sulphur	30	12	40
2·5 per cent lime-sulphur	30	28	93
5·0 per cent lime-sulphur	15	15	100
10·0 per cent lime-sulphur	15	15	100
5·0 per cent captan	15	0	0
4·0 per cent dispersible sulphur	15	0	0
Untreated	15	0	0

These results showed that all concentrations of lime-sulphur caused high mortality to *P. ambiguus* nymphs, whilst captan and dispersible sulphur, at fifty and five times the normal orchard strength respectively, had no perceptible toxic effect. That deaths were due to fumigant rather than contact action was suggested by the results of an additional treatment, not included in Table I, whereby

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1 ml. of 2 per cent lime-sulphur was substituted for water at the bottom of the tubes. This did not penetrate as a liquid to the filter paper discs and so the insects were protected from direct contact with the lime-sulphur. The 60 per cent mortality observed indicated that a toxic vapour was evolved.

Comparison of the fumigant and contact action of lime-sulphur

Another experiment was designed to obtain confirmation that the mortality previously observed was due to a fumigant effect. Apple leaves, dipped in 5 per cent lime-sulphur and allowed to dry for three hours, were placed in tubes which were either corked as before or ventilated by drawing moist air through them at the rate of 1 cc. per tube per second. Four insects were placed in each tube.

Table II shows that insects exposed to a dry deposit of 5 per cent lime-sulphur, under conditions

TABLE II

THE TOXICITY OF DRY LIME-SULPHUR DEPOSITS TO *P. AMBIGUUS*

Treatment		No. of insects	Number dead after			
			2 hr	20 hr	44 hr	70 hr
Untreated	Ventilated	16	0	0	1	5
	Unventilated	16	0	0	0	2
5 per cent lime-sulphur	Ventilated	16	0	0	1	4
	Unventilated	16	13	16	16	16

of adequate ventilation, suffered no greater mortality than those on untreated leaves, indicating that there was no contact effect. In an enclosed space without ventilation, mortality was high, even after only two hours, supporting the previous conclusion that toxicity resulted from a fumigant action. Deaths occurring in the controls towards the end of the observation period were mainly due to cannibalism during moulting.

So far test insects had been placed only on leaves with dry deposits of lime-sulphur, but under normal orchard conditions they may be wetted by spray as well as being exposed to liquid deposits on leaves. To simulate these conditions a further experiment was performed in which insects were sprayed by an atomizer with 2·5 per cent lime-sulphur until completely enveloped by the liquid. Some were then transferred to tubes containing leaves still wet from being dipped in 2·5 per cent lime-sulphur whilst others were similarly placed on clean leaves. Half of each set of tubes was corked and the remainder ventilated as in the previous experiment.

TABLE III

THE TOXICITY OF LIQUID DEPOSITS OF 2·5 PER CENT LIME-SULPHUR TO *P. AMBIGUUS*

Treatment		No. of insects	Number dead after		
			1 hr	4 hr	24 hr
Sprayed insects	Ventilated	16	0	0	1
Untreated leaves	Unventilated	16	3	7	13
Sprayed insects	Ventilated	16	0	0	1
Dipped leaves	Unventilated	16	15	16	16

Again, as will be seen from Table III, ventilation eliminated any toxic effect arising from lime-sulphur, even for insects which had been thoroughly sprayed and then placed on wet leaves. All the sprayed insects placed on dipped leaves and confined in closed tubes died within an hour or two of treatment and those placed on clean leaves under similar conditions suffered high mortality within 24 hours although the total amount of lime-sulphur was much less.

Persistence of toxic effects from lime-sulphur deposits

To obtain information on this subject an apple seedling was sprayed to run-off with 2·5 per cent lime-sulphur. Leaves were removed at intervals of 4, 24 and 48 hours after spraying and placed together with three insects, in corked tubes. Each treatment was replicated five times and mortality was recorded 24 hours after each test began.

TABLE IV

THE EFFECT OF AGEING ON TOXICITY OF LIME-SULPHUR DEPOSITS

Treatment	No. of insects	No. dead after exposure to deposits of age		
		4-28 hr	24-48 hr	48-72 hr
Untreated	15	0	1	0
2·5 per cent lime-sulphur	15	15	9	0

The results (Table IV) show that, with dry deposits on detached leaves, toxicity had decreased by 24 hours and none was detectable after 48 hours.

The effect of hydrogen sulphide on nymphs of *P. ambiguus*

It is known that hydrogen sulphide is given off from drying lime-sulphur deposits, and, as this gas has been credited with insecticidal properties by Weedon, Hartzell and Setterstrom (5), it seemed to be the most likely cause of the mortality noted in the previous experiments. To test this theory insects were exposed to varying concentrations of the gas.

Ten nymphs, together with aphids and an apple leaf, were placed in uncorked glass tubes, the upper half-inch of the inner surface of each tube being coated with polytetrafluoroethylene to prevent the insects escaping. Each tube was placed in a wide-mouthed, 250 ml. conical flask in such a way that it could not fall over.

Various concentrations of hydrogen sulphide were obtained by mixing appropriate amounts of standard aqueous solutions of sodium sulphide with an excess of dilute sulphuric acid. A measured quantity of standard sulphide solution was pipetted into the bottom of the flask, followed by the requisite amount of acid. The flask was immediately stoppered and gently shaken. To the control only dilute sulphuric acid was added.

TABLE V

THE TOXICITY OF VARIOUS CONCENTRATIONS OF HYDROGEN SULPHIDE TO NYMPHS OF *P. AMBIGUUS*

Amount of Na_2S(g.)	H_2S equivalent(μg.)	Percentage knock-down after			
		7 min.	15 min.	20 min.	24 hr
0·001	436	100	100	100	100
0·0005	218	—	100	100	100
0·00025	109	—	100	100	100
0·00015	65	—	100	100	100
0·00012	52	—	—	100	100
0·0001	43·6	—	—	20	20
0·0001	43·6	—	—	50	50
0·0001	43·6	—	—	60	60
0·000075	33	0	0	0	0
0·00005	22	0	0	0	0
Nil + H_2SO_4	0	0	0	0	0

The results (Table V) show that the lowest level of hydrogen sulphide which gave a complete kill of nymphs of *P. ambiguus* was 52 μg./250 ml., or 208 μg./litre ; a partial kill was obtained with 43·6 μg./250 ml. (174 μg./litre) but no toxic effect was noted with lower concentrations. Cupples, Yust and Hiley (3) reported that 25 mg./litre was necessary to kill 99 per cent of California red scale in a 25 minute exposure. Thus it would seem that *P. ambiguus* is susceptible to much lower concentrations than this scale insect. It was noted during this experiment that with all concentrations the maximum knock-down was obtained within 20 minutes, showing that rapid diffusion of H_2S took place.

Conclusions

These experiments have shown that lime-sulphur is toxic to nymphs of *P. ambiguus* only under conditions where fumigant action is possible and also that the nymphs are extremely susceptible to fumigation with hydrogen sulphide. It is known that hydrogen sulphide is evolved from solutions of polysulphides and from deposits of lime-sulphur. It may, therefore, be inferred that, in the orchard,

conditions which favour the evolution of hydrogen sulphide and its accumulation would lead to toxicity to *P. ambiguus*. Under humid conditions, for instance, the drying of the fresh lime-sulphur deposit and the time during which the gas can be evolved will be protracted, and still air will favour the accumulation of local pockets of this gas.

Under experimental conditions it was shown that slight air movement through a one-inch diameter tube was sufficient to prevent mortality, even when freshly sprayed insects were placed on a leaf containing a liquid deposit of 2·5 per cent lime-sulphur. It is, therefore, doubtful whether insect mortality would occur on the surfaces of exposed and expanded leaves, but the toxic hazard would be much greater where overlapping leaves or other forms of shelter provided suitable sites for a higher concentration of gas to develop. Nymphs of *P. ambiguus* are present from the green cluster stage onwards and many can be found among the flower bud stalks and in folds of partially opened leaves. Mortality from hydrogen sulphide may well occur in such situations, especially just after the application of a lime-sulphur spray.

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Summary

Laboratory experiments have shown that wet and recently dried deposits of 2·5 per cent lime-sulphur on apple leaves are highly toxic to second and third instar nymphs of *Psallus ambiguus* (Fall.) when placed in closed glass tubes. Similar experiments in aerated tubes caused no mortality. Tests with hydrogen sulphide gave 100 per cent kill with a 20 minute exposure to concentrations as low as 208 μg./litre. From these results it is inferred that the toxicity of lime-sulphur is due to the fumigant action of the hydrogen sulphide evolved. It was also shown that toxicity of the dry deposit decreased with age until, at 48 hours, it caused no mortality. No toxic effects were observed with 5·0 per cent captan or 4·0 per cent dispersible sulphur.

References

(1) Collyer, E. (1953). Biology of some predatory insects and mites associated with the fruit tree red spider mite (*Metatetranychus ulmi* (Koch)) in south-eastern England. III. Further predators of the mite. *J. hort. Sci.*, **28,** 98-113.

(2) ——— (1953). The effect of spraying materials on some predatory insects. *Rep. E. Malling Res. Sta. for 1952,* 141-5.

(3) Cupples, H. C., Yust, H. R., and Hiley, J. (1936). Tests for possible substitutes for hydrocyanic acid in fumigation of California red scale. *J. econ. Ent.*, **29,** 611-8.

(4) Shepard, H. H. (1951). The chemistry and action of insecticides. McGraw-Hill, New York.

(5) Weedon, F. R., Hartzell, A., and Setterstrom, C. (1940). Toxicity of ammonia, chlorine, hydrogen cyanide, hydrogen sulphide and sulphur dioxide gases. V. Animals. *Contrib. Boyce Thompson Inst.*, **11,** 365-85.

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PLANT PROTECTIVE CHEMISTRY

THE PROBLEM OF ACARICIDE-TOLERANT STRAINS OF THE FRUIT TREE RED SPIDER MITE, *METATETRANYCHUS ULMI* (KOCH) IN SOUTH-EAST ENGLAND

By ELSIE COLLYER and A. H. M. KIRBY

Trials were conducted in Essex from 1944-53 by East Malling Research Station under the auspices of the Agricultural Research Council, the Associated Fruit Growers of Essex Ltd., and the Pettar Society of Winter Wash Manufacturers, with a view to the control of the fruit tree red spider mite, *Metatetranychus ulmi* (Koch). When these trials finished the opportunity arose to follow up the use there of certain representative acaricides and to observe any long-term effects that might emerge. The policy adopted was to apply two such materials in association with a minimal programme of insecticides and fungicides designed, as far as possible, to encourage the development of useful populations of predacious insects and mites ; this procedure would not normally give a clear picture of the relative merits of the acaricides, as these would be obscured by the enhanced activity of predators on the plots carrying larger numbers of mites, but a difference in performance did emerge in the first year of the series, 1954, and in the last, 1958.

The acaricides used in 1954 and 1955 were the best one to emerge from the joint trials mentioned above, namely, 4-chlorophenyl 4-chlorobenzenesulphonate (chlorfenson), and the equally interesting British development, 4-chlorobenzyl 4-chlorophenyl sulphide (chlorbenside) (Cranham, Higgons and Stevenson, 1953). After an interim period in which chlorbenside was applied to the whole orchard (1956-7), a further comparative study was made in 1958, in which chlorbenside and a new organophosphorus acaricide, diethyl *S*-2-diethylaminoethyl phosphorothiolate (amiton) (Ghosh and Newman, 1955 ; Baldit, 1958), having a different mode of action, were used. Although satisfactory control was obtained with both materials in the 1954-5 trials, and with amiton in 1958, chlorbenside was shown to be ineffective in 1958 ; this was confirmed by laboratory studies and chemical measurement of deposits.

Trials in 1954-5

Experimental

Materials.—(*a*) Chlorbenside was used as a 20 per cent dispersible powder based on kaolin with suitable surface-active agents.

(*b*) Chlorfenson was obtained as a technical product, setting-point 82·5° C., and was made into sufficient wettable powder, containing 20 per cent actual chlorfenson, with kaolin and goulac, for the two years.

Layout.—The orchard, 5 acres of Worcester Pearmain with Laxton's Superb at 1 in 9, on M.II, planted in 1933 at 20 ft square, was divided diagonally to give nine plots with recorded trees separated as far as possible from those in adjacent treatments, thus providing three replicates of three treatments. A few unsprayed trees at one end of the orchard served as controls until mid-July in both years.

Treatments.—(*a*) Chlorfenson, 0·1 per cent, at pink-bud only (4th May 1954 ; 4th May 1955).

(*b*) Chlorfenson, 0·025 per cent, twice post-blossom (17th June and 5th July 1954 ; 13th June and 4th July 1955).

(*c*) Chlorbenside, 0·025 per cent, twice post-blossom (dates as treatment (*b*)).

Routine sprays.—These were kept to sulphur for diseases, nicotine for sawfly, and lead arsenate for codling moth. However, an application of DDT emulsion was necessary in April 1954, to deal with an attack of apple-grass aphid ; this was avoided in 1955 by applying a 5 per cent tar oil wash in the winter 1954-5.

Results

In spite of high winter-egg populations (approximately 1,000 per 10 in. shoot) in December 1943, all treatments gave good control at first. On the trees sprayed at pink-bud, however, mites became

numerous by mid-August. The other treatments were effective through the summer ; by 10th September 1954, there were 3 mites-plus-eggs present per leaf on chlorbenside plots compared with 7 on chlorfenson plots and this difference was significant at $P<0.001$. As there were very few black-kneed capsids, no typhlodromids, and no marked difference in populations of other predators on these plots, this would seem to be a fair assessment of the relative performance of the two acaricides, applied in very similar formulations. An apparently similar difference between these two treatments emerged at the end of the 1955 season, in which both materials gave ample commercial control, but it was not significant even at $P=0.05$, probably due to the fact that the black-kneed capsid was building up especially on the chlorfenson plots. In this year, the pink-bud treatment broke down early in July and had to be sprayed again in August.

Interim period, 1956-7

During this period, chlorbenside was applied to the whole orchard, using the commercial wettable powder twice in 1956 and once in 1957 ; a second spraying with the commercial emulsifiable concentrate was made in 1957. Spraying dates were : 6th and 26th June 1956 ; 15th May and 24th July 1957. Routine sprays were as before ; in addition tar oil was applied in the second winter (1956-7).

Satisfactory control appeared to be achieved in 1956, although work carried out in an adjacent locality indicated that the season was very unfavourable for mites (Collyer and Kirby, 1959) (cf. Fig. 2) ; on 3rd August, the number of mites-plus-eggs per leaf averaged one. There were fair numbers of black-kneed capsids present averaging 22 on 48 branches, but the very low levels of mite caused these numbers to fall and this predator failed to lay eggs, being absent from the orchard in 1957 and 1958.

Mite numbers were low in June 1957, following the mid-May spraying, but rose to 17 mites-plus-eggs per leaf in July. The application of the emulsifiable form of chlorbenside on the 24th July failed to cause any reduction of numbers as judged by the record (20 per leaf) taken on 21st August. This is reflected in the high density of winter egg populations, in the region of 4,000 eggs per 10 in. wood, recorded in December, 1957. However, no bronzing of leaves or dispersal of mites was detected.

1958 Trial

Experimental

Materials.—(*a*) Chlorbenside was again applied as the commercial 20 per cent wettable powder.

(*b*) Amiton was used as a commercial, water-soluble product containing 75 per cent of the hydrogen oxalate salt.

Layout.—This was simplified to divide the orchard into four rectangular quarters, allowing two replicates of two treatments. Treatments were applied to diagonally opposite quarters, and records were taken on four separate pairs of Worcester Pearmain trees in each quarter.

Treatments.—(*a*) Chlorbenside was applied on 5th June and 10th July, at 0·02 per cent ; a third application at 0·04 per cent was made on 31st July.

(*b*) Amiton, applied once only on 13th June, was used at a rate of 1·4 oz. amiton, dissolved in 250 gallons of water, per acre.

Routine sprays.—Tar oil was applied to the whole orchard in January 1958, and the routine fungicide and insecticides were as in previous years.

Results

Action of acaricides.—One application of amiton gave an excellent kill of mites, and of the larvae that hatched subsequently, and very little build-up occurred later in the season (Table I). In sharp contrast, there was very little check to development following applications of chlorbenside at the

TABLE I

NUMBERS OF MITES-PLUS-EGGS PER LEAF IN THE 1958 TRIAL

Treatments	4 June	13 June	19 June	27 June	10 July	24 July	13 Aug.	11 Sept.
Chlorbenside ..	14	35	55	24	77	162	153	133
Amiton	19	36	17	6	0·5	0·2	0·25	6·2

Double vertical lines indicate the application of sprays.

recommended rate, nor indeed when it was applied at double that rate. Bronzing was seen on chlorbenside plots in August, becoming severe in September though little leaf-fall occurred before October.

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There was dispersal from these trees on to the amiton plots, penetrating three to four trees into the six rows, and affecting at least half of the recorded trees. Consequently there were more mites on 11th September (Table I) than would be expected following amiton.

Influence of predators.—Black-kneed capsids and typhlodromid mites were absent in 1958 as well as 1957. The only predator of any consequence was *Anthocoris nemorum* (L.) ; it appeared to be unaffected by the treatments and, as is to be expected from its great mobility, became distributed in the orchard in direct proportion to the mite densities. Very few were present on the amiton plots, numbers falling with the mite numbers (Fig. 1) ; this emphasizes the efficacy of the acaricide. Numbers

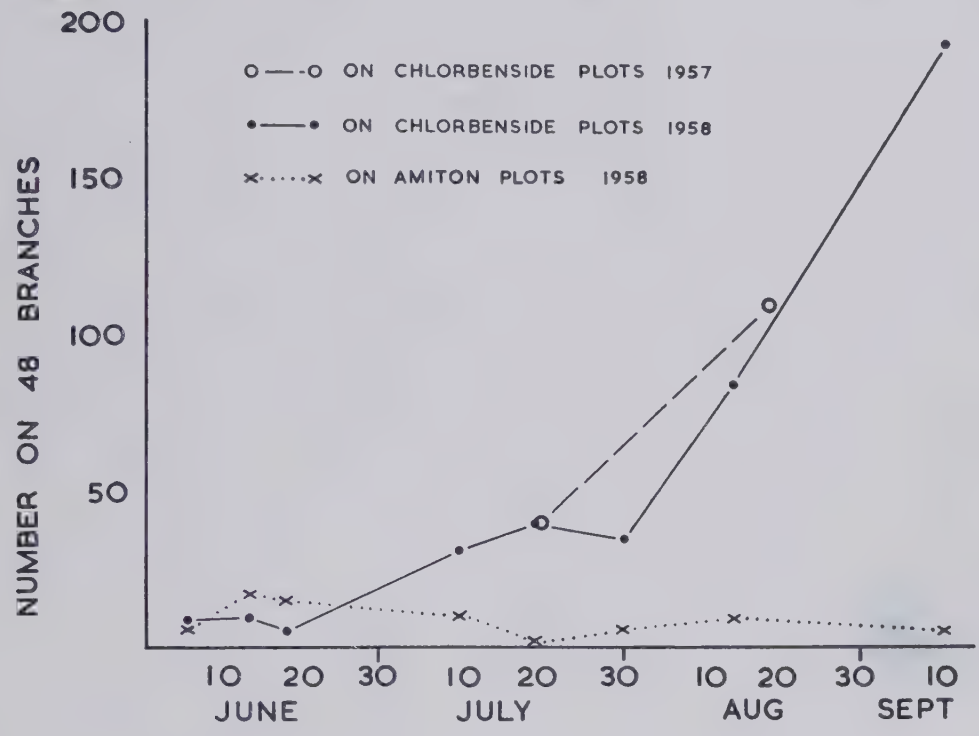

FIG. 1

Numbers of *Anthocoris nemorum* (L.) recorded in 1957 and 1958

on the chlorbenside-treated trees, which had been high in 1957, rose as the mite numbers rose, to the unusually high level of 4 per branch in September, undoubtedly mitigating the failure of chlorbenside.

But for this unequal distribution of *A. nemorum* and for the dispersal which occurred by September, the large difference in winter-egg populations recorded in November 1958 (1,495 eggs per 10 in. wood on chlorbenside trees, and 98 on amiton trees) would doubtless have been even larger.

Weather records

The average maximum temperatures for each month, May-September, in each of the years 1954-8, and the rainfall for these months and each season are given in Fig. 2. Although rainfall totals for the first four years are very similar, great differences in distribution are evident, especially between 1955 and 1956. The exceptionally heavy rainfall throughout the 1958 season was clearly no deterrent to the development of large mite populations, but the temperatures were higher, especially in August, than in 1956 when mite populations failed to build up.

Results of laboratory investigations

Biological

Observations were made in the laboratory, using sprayed foliage and mites from the experimental orchard, except in the final year when mites unaffected by chlorbenside were collected from another site. The leaves were placed, lower side uppermost, on cotton wool in water in petri-dishes and mites transferred on to them when required.

Table II

Effect of chlorbenside and chlorfenson on summer eggs, 1954-56

			1954				1955			1956	
			First spraying		Second spraying		Second spraying			First spraying	
Age of deposit in days			4		1		2			8	
	Leaves	Mites	No. of eggs	% hatch	No. of eggs	% hatch	No. of eggs	% hatch	% larvae alive	No. of eggs	% hatch
Chlorbenside	Sprayed	Sprayed	109	0	50	0	11	0	—	79	1
	Sprayed	Unsprayed	70	0	50	0	188	3	14	208	1
	Unsprayed	Sprayed	62	2	20	0	25	50	42	—	—
	Field-sprayed eggs		150	0	150	0	—	—	—	85	1
Chlorfenson	Sprayed	Sprayed	16	0	40	0	38	32	56		
	Sprayed	Unsprayed	100	0	100	2	200	50	50		
	Unsprayed	Sprayed	58	30	16	50	96	80	90		
	Field-sprayed eggs		156	0	150	2	—	—	—		
	Unsprayed	Unsprayed	91	90	—	—	35	67	95		

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Chlorbenside and chlorfenson 1954-6.—When these materials were first used they were regarded as mainly ovicidal, but the following effects were all observed : killing of eggs already present and of those laid subsequently for a considerable number of days, killing of larvae and some nymphs at the time of spraying and of larvae hatching subsequently ; reduction of the egg-laying capacity of the

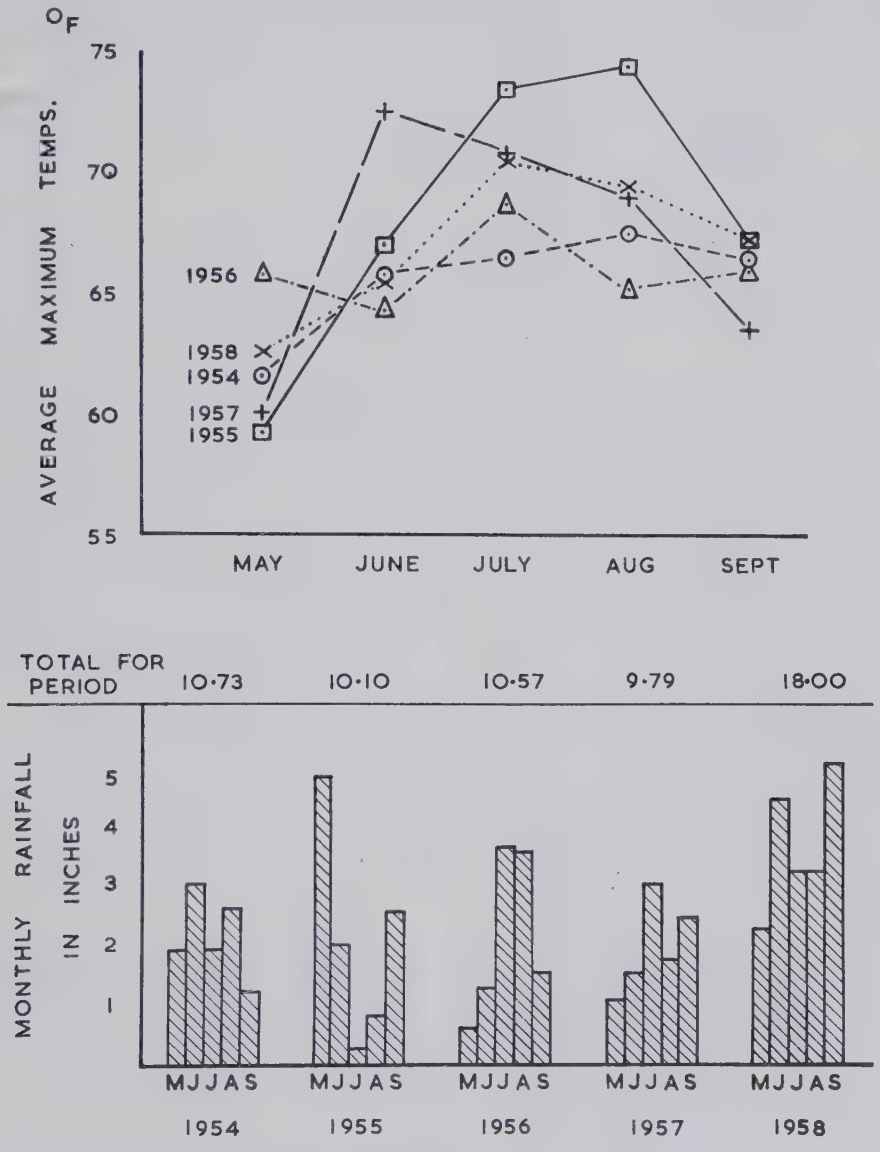

FIG. 2

Average monthly maximum temperatures, total rainfall for the 5-month period, and monthly rainfall for May-September, 1954-8, at the Essex Institute of Agriculture, Writtle, Essex.

females and infertility of eggs laid by sprayed females. The results obtained are summarized in Table II. Chlorbenside gave a complete kill of eggs in the first year ; chlorfenson was somewhat less effective in that up to 50 per cent of the eggs laid by sprayed females on unsprayed foliage were fertile. In 1955, both materials showed less effect, particularly chlorfenson, when there was a considerable hatch of eggs and survival of the larvae hatching from them, but the one test carried out in 1956 showed that the eggs were very susceptible to chlorbenside at that time.

No tests were made in 1957 ; in the light of subsequent developments, this was unfortunate, especially as the application of chlorbenside in late July, made without the authors' knowledge, seems to have had less effect than previous applications.

TABLE III

EFFECT OF CHLORBENSIDE ON SUMMER EGGS, 1958

		First spraying 0·02%		Second spraying 0·02%		Third spraying 0·04%	
Age of deposit in days		I		II		I	
Leaves	Mites	No. of eggs	% hatch	No. of eggs	% hatch	No. of eggs	% hatch
Sprayed	Sprayed	250	65	251	70	200	69
Sprayed	Unsprayed	300	66*	330	25*	238	5*
Unsprayed	Sprayed	210	68	206	70	333	87
Unsprayed	Unsprayed	250	82*	220	63*	220	65*
Field-sprayed eggs		—	—	253	85	362	93

* The ' unsprayed ' mites used in this experiment at the time of the first spraying were taken from the plots to be sprayed later with amiton, but which in previous years had been sprayed with chlorbenside. For the laboratory tests following the second and third field spraying, unsprayed mites were collected from a different orchard, where no acaricide had been used at any time.

Chlorbenside 1958.—In 1958, laboratory studies confirmed the field observations that this chemical was having very little effect on any stage of the mite (Table III). Even when a third application was made at twice the normal strength, up to 93 per cent of the sprayed eggs hatched, sprayed females laid a normal number of fertile eggs and even on sprayed leaves most of these hatched normally and the larvae survived. On the other hand, where females from a Kent orchard that had never received any acaricide were placed on sprayed leaves from the experiment after the third application, there was up to 95 per cent mortality ; the larger percentage hatch after the second application probably reflects the fact that the leaves were collected after ten days when a large part of the chemical had gone (cf. Fig. 3). The normal hatch of eggs laid by unsprayed females on leaves collected after the first application of chlorbenside, was 66 per cent. These unsprayed females had been taken from the other plots in the orchard (not then sprayed with amiton). This percentage hatch supports evidence from the orchard data that tolerant mites were already prevalent in the orchard.

Amiton 1958.—Leaves collected from the orchard on the day of spraying with amiton (13th June) were taken into the laboratory. Of 50 unsprayed females placed on these leaves, all were dead within 24 hours without laying eggs. Further leaves were collected on 12th July, 21st July, 1st August and 10th August ; on the day following each collection, 50 females were placed on 10 leaves and all died within 48 hours after laying 0, 60, 48, 35 eggs, respectively. All of these eggs hatched, although the resulting larvae died within a few hours. On 11th September, 13 weeks after the application, 20 females were placed on each of seven leaves ; within four days all were dead except 3 and 2 respectively on two leaves, i.e. 96·5 per cent died.

Chemical estimation of chlorbenside in 1958

No chemical analyses were carried out in the 1954-5 trial. However, in view of reports of failures elsewhere to control mite populations in 1957, and perhaps also in 1956, with either chlorfenson or chlorbenside, it was decided that the level of chlorbenside actually applied in the 1958 trial, and of the rate of loss thereafter, would need to be established. Twenty large leaves were collected around each recorded tree, between 5 and 7 feet from the ground, immediately after the first application of chlorbenside, and immediately before and after the second and third applications. Further samples were taken 2-42 days after the third application.

Leaves taken immediately after an application were combined for pairs of trees, giving eight samples ; leaves from two pairs were combined for later samplings and in one case from all eight trees in each plot, giving four and two samples, respectively. The leaves were extracted with hot organic solvent, the chlorbenside (or its oxidation products that are also acaricidal) was then oxidized completely to the sulphone which was extracted, nitrated and estimated colorimetrically ; this method is a modification of that described by Higgons and Kilbey (1955). The levels of the initial deposits and the rate of loss of chlorbenside are shown in Fig. 3.

Discussion

The results of the 1954-5 trial make it clear that adequate control of *M. ulmi* could be obtained in this orchard at that time with two applications at 0·025 per cent of either chlorbenside or chlorfenson, the first application being made when most of the winter eggs had hatched. One application of chlorfenson at pink-bud at four times the rate prevented an early build-up in 1954, but was not so effective

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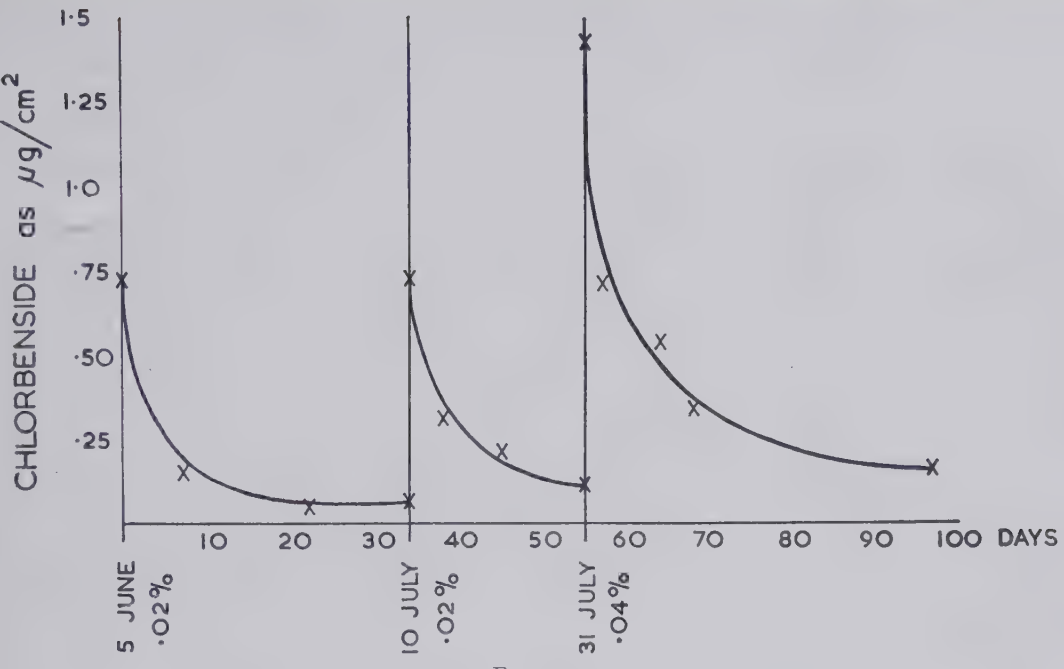

FIG. 3

Deposition and persistence of chlorbenside on leaves, determined chemically, in the 1958 trial

in 1955, when a second application was necessary, even in the presence by July of considerable numbers of black-kneed capsid and *A. nemorum*.

The use of chlorbenside twice in 1956 and 1957, in conjunction with the presence of predatory insects, kept the populations of *M. ulmi* at low levels until late summer of 1957 when they gradually built up and the winter egg density was high. But in 1958 the performance of chlorbenside was in complete contrast with that of the early years and with that of amiton which provided striking and prolonged control ; even when chlorbenside was applied at 0·04 per cent, a very large percentage of sprayed eggs hatched, adult females survived and laid normal numbers of eggs which hatched normally. The chemical estimations showed that the amount of chemical to be expected from each application was in fact present, and that the rate of loss was normal, so that the failure to achieve control of the pest cannot be attributed to any shortage of toxicant. This seems to leave only the possibility of resistance to chlorbenside on the part of the mites themselves.

The phenomenon of resistance to insecticides, including acaricides, is not new. By 1950, reports had appeared on resistant races of the glasshouse mite, *Tetranychus telarius* (L.) on greenhouse roses treated with parathion in the U.S.A. (Garman, 1950), and the same phenomenon on carnations in Germany was reported by Dosse (1952). Four years' use of this acaricide was followed by failure to control *M. ulmi* on apple in Washington State (Newcomer and Dean, 1952). The problem has also proved acute with the citrus red mite, *Panonychus*(=*Metatetranychus*) *citri* (McG.) (Jeppson, Jesser and Complin, 1958). Resistance is by no means confined to parathion, but may already exist or be later acquired towards many other acaricides. Gasser (1957) quotes M. M. Barnes as reporting that, in California, *M. ulmi* was very resistant to parathion, malathion, demeton, and diazinon, while only just showing resistance to Trithion, but nevertheless resistant to chlorfenson and chlorbenside. Private communications from Canada indicate that *M. ulmi* in British Columbia and in Nova Scotia is showing tolerance towards fenson, chlorfenson, and chlorbenside, as well as to parathion. It is clear, in fact, that resistance may develop to most, if not all, compounds in a single class, or to compounds in more than one class.

Under artificial conditions, resistance may be retained for years (Gasser, 1957) ; in nature, cross-breeding with non-resistant mites from elsewhere may restore the situation gradually.

It would seem that future efforts must lie along two lines :

(*a*) The search for new acaricides of novel structure and, if possible, mode of action, and for the best way to use them so as to prolong their effective life.

(*b*) attempts should be continued to devise spray programmes that will permit predacious insects and mites to play as large a role as possible in pest control.

The curiously haphazard manner in which resistance develops towards two or more acaricides suggests that it will be possible to use compounds of a different chemical group from the one to which the failing compound belongs, and so to switch to more than one series before all the possibilities are exhausted. Thus in north American areas where fenson, chlorfenson, and chlorbenside are failing, there is no evidence that mites are resistant yet to several of the newer acaricides. It is probable that the use of one compound until it proves ineffective and then another in the same way and so on, is less likely to prove effective in the long run than annual changes among several types of compound whereby tolerance towards any one of them may be very long delayed.

The attempt to use predacious species as a regular, reliable mainstay of the attack on phytophagous mites is beset with many problems, including the fact that the predatory insects must have an adequate level of food or they disappear as the black-kneed capsid did when the mite level fell too low in 1956 in the work described above. Added to this is the problem of finding toxicants that will control pests such as codling moth or diseases such as powdery mildew without also eliminating the predacious species. These problems may yet be solved ; as far as scab is concerned, one such solution is already available (Collyer and Kirby, 1955, 1959). At present, it is only possible to make use of predacious species to control the fruit tree red spider mite if the grower is prepared to accept some degree of infestation by a few other pests and mildew.

Future development must depend to some extent on understanding the mode of action of existing acaricides. The importance of assessing the activity of a compound against more than one stage in the life-history of mites was demonstrated by Ebeling and Pence (1954) who showed clearly that the most susceptible stage of *T. telarius* to chlorfenson and dinex is not the egg or the adult but the larva. Meltzer (1955) added the important observation that eggs laid on a treated leaf may be more easily killed than eggs present at the time of treatment, and also showed that the stage of *T. telarius* most susceptible to many so-called ovicides and to DNOPC is the larva. The use of the term ' summer ovicide ' is therefore misleading, and one of us (Kirby, 1956) has already suggested that the term ' acaricide ' be used for any compound having economic toxicity towards any stage of a mite.

Another mechanism of action not observable in most routine screening tests for acaricides was demonstrated by Meltzer and Dietvorst (1957) who showed that the viability of eggs laid by females of *T. telarius* after feeding on foliage treated with fenson, chlorbenside, or, especially, a tetrachlorodiphenyl sulphone, was markedly reduced. This mechanism appeared in his experiments to be of less importance for *M. ulmi*, but the results given in Table II indicate that it was operating in the Essex trials, more so in the case of chlorbenside than in that of chlorfenson. Indeed, the failure of many materials to kill adult females is not of great consequence if the action on the unlaid eggs is of sufficient magnitude. This mechanism, however, appears to have been affected by the development of tolerance to as great an extent as the direct action on the egg already laid.

Acknowledgements

The authors wish to thank their colleague, Dr. A. M. Massee, O.B.E., for his constant interest and encouragement in this work. Their thanks are also due to the Governors of the Essex Institute of Agriculture for permission to use one of their orchards and to the staff of the Fruit Section for much willing help, to Ward, Blenkinsop and Co., Ltd., for a gift of technical chlorfenson and to Plant Protection Ltd., who kindly carried out the formulation of the chlorfenson used in the 1954-55 trial.

Summary

Satisfactory control of the fruit tree red spider mite, *Metatetranychus ulmi* (Koch), was obtained in an Essex orchard in 1954 and 1955 with two post-blossom applications of either chlorfenson or chlorbenside. A single pink-bud application of chlorfenson at a heavier rate was ineffective in 1955.

Following routine applications of chlorbenside in the same orchard in 1956 and 1957, a heavy winter egg population was present in 1957-8. Chlorbenside applied post blossom in 1958 failed to kill summer eggs or larvae, or to affect the production or viability of summer eggs laid by sprayed female mites. Chemical determinations showed that chlorbenside was deposited and weathered in a normal manner on leaves from the experimental plots, and laboratory tests showed that eggs, laid by female mites taken from trees never sprayed with acaricides, largely failed to hatch.

In contrast to the 1958 result with chlorbenside, excellent control was obtained in the same orchard on plots sprayed once in mid-June with the organophosphorus acaricide, amiton. Leaves remained highly toxic to adult female mites and larvae for at least thirteen weeks.

The conclusion drawn from these trials is that mites now present in this orchard are tolerant of, or resistant to, chlorbenside but not amiton. Judging by experiences in other parts of the world, these mites may well be tolerant of acaricides of the fenson family, and it is to be expected that tolerance

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to other acaricides, particularly those of the organophosphorus type, might also appear. The problems associated with this phenomenon are briefly discussed.

References

Baldit, G. L. (1958). Amiton—a new acaricide and scalicide. *J. Sci. Food Agric.*, **9**, 516-24.

Collyer, E., and Kirby, A. H. M. (1955). Some factors affecting the balance of phytophagous and predacious mites on apple in south-east England. *J. hort. Sci.*, **30**, 97-108.

———, ——— (1959). Further studies on the influence of fungicide sprays on the balance of phytophagous and predacious mites on apple in south-east England. *J. hort. Sci.*,**34**, 39-50.

Cranham, J. E., Higgons, D. J., and Stevenson, H. A. (1953). *p*-Chlorbenzyl *p*-chlorphenyl sulphide : a new ovicide for control of red spider. *Chem. and Ind.*, 1206-7.

Dosse, G. (1952). The greenhouse spider mite *Tetranychus urticae* Koch *forma dianthica* and its control. Höfchen-Briefe (English edition), **5**, 239-67.

Ebeling, W., and Pence, R. J. (1954). Susceptibility to acaricides of two-spotted spider mites in the egg, larval and adult stages. *J. econ. Ent.*, **47**, 789-95.

Garman, P. (1950). Parathion resistant red spiders. *J. econ. Ent.*, **43**, 53-6.

Gasser, R. (1957). Ueber den Stand der Resistenz von Spinnmilben gegenüber Akariziden. *4th int. Congr. Crop Prot.* Hamburg (cyclostyled).

Ghosh, R., and Newman, J. F. (1955). A new group of organophosphorus pesticides. *Chem. and Ind.*, 118.

Higgons, D. J., and Kilbey, D. W. (1955). Colorimetric analysis of *p*-chlorobenzyl *p*-chlorophenyl sulphide (chlorbenside) residues in plant and animal tissue. *J. Sci. Food Agric.*, **6**, 441-8.

Jeppson, L. R., Jesser, M. J., and Complin, J. O. (1958). Resistance of the citrus red mite to organic phosphates in California. *J. econ Ent.*, **51**, 232-3.

Kirby, A. H. M. (1956). In discussion (p. s101-2) on Cranham, J. E. Control of red spider on fruit. *J. Sci. Food Agric.*, **7**, s93-102.

Meltzer, J. (1955). Het onderzoek van acariciden en spintoviciden in het laboratorium. *Tijdschr. PlZiekt.*, **61**, 130-42.

———, and Dietvorst, F. C. (1957). Action of Tedion on eggs and ovaries of spidermites. *Tijdschr. PlZiekt.*, **64**, 104-10.

Newcomer, E. J., and Dean, F. P. (1952). Orchard mites resistant to parathion in Washington. *J. econ. Ent.*, **45**, 1,076-8.

FRUIT STORAGE INVESTIGATIONS

STORAGE CONDITIONS IN RELATION TO *GLOEOSPORIUM* ROTS

By H. B. S. MONTGOMERY

During the past three years samples of Cox's Orange Pippin have been received from commercial growers in various parts of England and their behaviour in cold and in gas storage compared. The samples in cold store (37°F.) were kept for approximately 14 weeks, and the similar samples in gas store (39°F., 3 per cent O_2 and 5 per cent CO_2) for about 18 weeks. In general, the percentage of apples with *Gloeosporium* rots was higher in gas store, probably mainly owing to the four weeks longer storage period, but certain samples in each year, especially in 1955-6 and in 1957-8, showed a reduced percentage of rotting apples from gas storage.

It was impossible in the time available to identify the species of *Gloeosporium* causing each rot in so many samples, but after the completion of the main examination in February 1958, rotting apples were taken from each of seventeen samples, some of which showed an increase and some a decrease in rotting with gas storage. The causal species of the sporing rots on these apples was determined on the basis of the shape of the spores. Where more than one species of *Gloeosporium* was identified in a sub-sample five additional apples from the sample were examined. This preliminary examination indicated that the different storage behaviour of these samples might be caused by a difference in the predominating species of *Gloeosporium*.

Larger sub-samples of up to 25 infected apples were, therefore, taken from four samples that showed increased rotting in gas storage and from four that showed a reduction, each being from a distinct orchard. In those samples where the percentage of rotting was low, the sub-sample was necessarily less than 25 apples even when every infected apple was taken. Each apple was numbered with Indian ink and every rotting spot producing spores was labelled and the fungus identified. If non-sporing rots were found, the apples bearing them were kept in a polythene bag at room temperature until as many of the rots as possible had produced spores and been identified. The results set out in Table I show that where there was a reduction in the number of rotting apples in the gas storage treatment the majority of the rots were caused by *G. album*, but where there was an increase, *G. perennans* was in the majority.

TABLE I

ROTTING OF SAMPLES IN COLD AND IN GAS STORE, IN RELATION TO PERCENTAGE OF ROTS DUE TO *GLOEOSPORIUM ALBUM*

Origin of sample	Percentage of apples infected with *Gloeosporium* spp.		No. of rots due to		Percentage of rots due to *G. album*
	Cold store	Gas store	*G. perennans*	*G. album*	
Eynsford	76	35	25	49	64
East Malling ..	34	9	4	26	87
Norwich	24	17	5	10	67
Beccles	57	23	4	94	96
Chelmsford ..	8	16	18	3	14
Canterbury ..	27	41	84	4	5
Burlingham ..	29	48	98	7	7
Marden	12	32	70	0	0

If further experiments confirm these clear indications, their practical application may be of considerable importance. There is some evidence that the incidence of *G. perennans* can be reduced by cutting out cankered shoots and branches, whereas the incidence of *G. album* is relatively little affected by such treatment. The combination, however, of strict orchard hygiene with gas storage may aid in controlling both species.

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Acknowledgements

Thanks are due to the many fruitgrowers who so generously gave the apples, and to Dr. M. P. Denne and Miss P. E. Hicks for their assistance.

Summary

The percentage wastage in samples of Cox's Orange Pippin apples due to *Gloeosporium* spp. was found to be lower in some commercially grown samples after 18 weeks gas storage than after 14 weeks cold storage. In these samples the predominating species was *G. album*, whereas *G. perennans* was predominating in samples where the rotting was greater after gas storage. It is suggested that strict orchard hygiene combined with gas storage may aid in controlling both species.

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Part IV

BULLETINS FOR FRUIT GROWERS

IRREGULAR CROPPING OF PEARS

By W. S. ROGERS and G. A. BOOTH

What makes a 'pear year'? Why do pear plantations yield well in some years and poorly in others? And why do a few crop tardily or always badly? Following reports from growers that pear plantations were cropping inconsistently or yielding less than expected, a tour was made in the Eastern Counties and Kent; and additional information was collected from growers, by an appeal in the press. The data are being studied in comparison with our own long-term trials. Particular attention is being paid to the variety Conference, which occupies about half the pear acreage of the country.

It is already obvious that pear yields fluctuate greatly; but, while a few pear orchards are cropping very poorly, others, over a period of years, are doing reasonably well. The Ministry of Agriculture's official figures for yields per acre of pears, given below, certainly show no steady decline, although because of changes in acreage and age of tree the figures can be regarded only as a rough approximation.

ESTIMATED YIELD, CWT. (112 LB.) PER ACRE, DESSERT AND COOKING PEARS, IN ENGLAND AND WALES (FROM 'AGRICULTURAL STATISTICS 1955-6')

1947	1948	1949	1950	1951	1952	1953	1954	1955	Average
52·2	41·8	51·2	27·8	37·3	54·1	42·4	41·1	57·3	45·0

Over these nine years, the mean estimated yield per acre of pears for the whole country is some 37 per cent below that of apples.

The purpose of this paper is to review briefly some of the factors already known to cause variation in yield, and to mention others that seem worth further study.

First, how serious is the variation? Fig. 1 shows graphically the yields of Conference on Quince A at East Malling from 1934 to 1958. The trees were 15 years old at the beginning of this period, and remained at 12 ft square until 1955, when alternate trees were removed. The yield varied from an equivalent of 24 to 966 bushels per acre (at 50 lb. per bushel). Such uneven cropping, which is typical of many pear orchards, is economically bad, both for the grower and the purchaser.

Fig. 1 shows that, although sometimes the yield fluctuates biennially, this is not consistent. The problem is one of *irregular*, rather than biennial bearing.

Climatic factors can greatly influence pear yields; the weather at blossom time seems of the greatest importance.

Frost

Pears blossom early (commonly mid-April to early May) and so are more subject to frost damage than apples. Pear blossom is damaged by temperatures of 26-27° F.; and screen temperatures of 26°F. or below were recorded during the blossom season of Conference in six of the 23 years whose results are shown in Fig. 1. In five of these six years the yield was less than 50 lb. per tree, in the sixth the yield was good, but the fruits were mis-shapen. In two of the frosty springs pollination conditions were also bad—a point considered later. It is clear, however, that frost can be a major cause of low yield in pears; and planting pears in frosty situations is very risky.

A secondary effect of loss of yield from frost is that while, as might be expected, the yield in the next year has been high, the yield the year after that has often been very low. This tendency to induce biennial bearing may be connected with an upsetting of the balance of growth, a matter which, as in apples, needs further research.

Wind

Wind may affect pear yields in several ways. Cold north and easterly winds at blossom time may lessen fruit set by desiccating the blossoms, or may limit activity of pollinating insects. Early

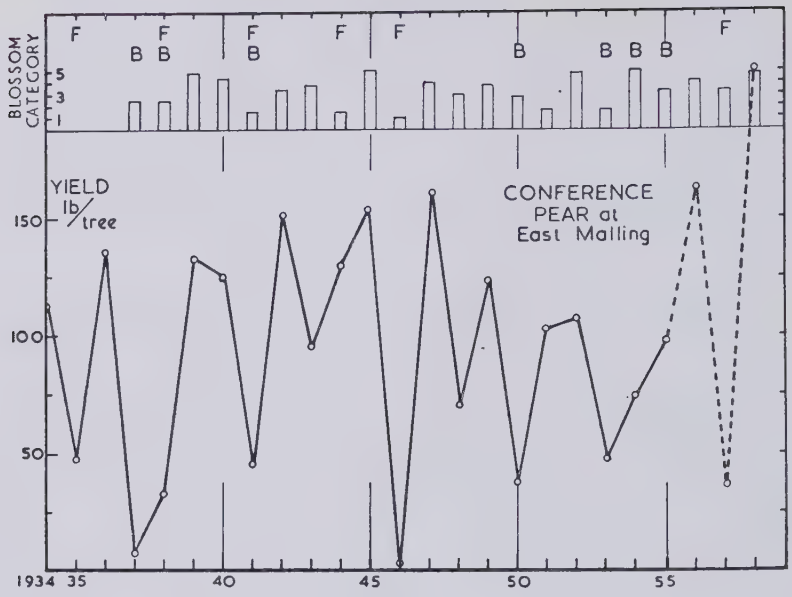

FIG. 1

Yields of Conference on Quince A at East Malling, from age 15 (1934) to 39 (1958). F = frost, of screen temperature 26° F. or below, during blossom period. B = bad pollinating conditions (see text). Blossom category records began in 1937. Alternate trees were removed in January 1956.

experiments at East Malling gave indications of increased blossom set where pear trees were sheltered by coir netting. Recent work in Holland showed good effects from shelter belts spaced 10 times their own height apart ; but the best result—an increase of 120 per cent in yield of Conference—was obtained within a distance of four times the height of the screen. This, though only a single year's result, and in an area more windy than most of England, is a striking effect.

Laceration and shredding of leaves by high winds has been noted in some seasons. Conference is particularly liable to this trouble, which must reduce the efficiency of the leaf. Such damage may not only affect the current year's fruit production, but also reduce the formation of fruit buds for the following year. Artificial defoliation of *apples*, in June, has been shown to lessen fruit bud formation—but only if the defoliation reaches about 80 per cent. Experiments on the defoliation of pears might give useful information.

The choice of sheltered sites, the use of windbreaks in certain areas, and the planting of pears close enough to shelter each other, will lessen risks from wind damage.

Sunshine, temperature and rainfall

We are now studying the effect of sunshine, temperature, and rainfall, using as a starting point the long-term records at East Malling. It is reported from the U.S.A. that moisture shortage 70 to 80 days after blossom, increased fruit bud initiation. On the other hand, we have evidence that under certain conditions drought can lead not only to smaller fruits but also to a lower yield in the following year.

Pears generally do best in a warm sunny climate ; half the pear acreage of England is in Kent, where the summer temperatures are among the highest of the country. Also the plantations which commonly do best are those fairly near the sea (if wind damage is avoided). Such a situation provides warmer nights and relative freedom from frost.

Not nearly enough is known of the temperature and water needs of pears, or of the periods in which certain levels of warmth and moisture are most important.

Pollination

Most pears, including Conference, Williams' Bon Chrétien, Doyenné du Comice and Laxton's Superb are diploid ; Pitmaston Duchess is triploid. No diploid or triploid pear sets a satisfactory

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crop with its own pollen ; therefore if insufficient or unsuitable pollinator varieties are planted, yields are likely to be poor, especially if weather is unfavourable at blossom time.

Conference, though sometimes reported to be self-fertile, is in fact self-incompatible. A comprehensive study at the John Innes Horticultural Institution, and a smaller one at East Malling both showed that self-pollinated flowers of Conference produced only 0·7 per cent fruits—a proportion quite inadequate for a commercial crop. By contrast, Conference cross-pollinated with many other varieties set high percentages of fruit. Among those noted as successful pollinators are Williams', Comice, and Dr. Jules Guyot. Conference may set parthenocarpic (seedless) fruits some of which are normal in shape, and this may account for earlier reports that Conference is self-fertile. Mostly, however, such fruits are badly mis-shapen and of poor market quality. Moreover, parthenocarpy does not always occur.

Field records of the effect of distance from pollinators are scanty. A New Zealand worker reported that in an orchard of Winter Nelis interplanted with Williams' Bon Chrétien at one row in four, the row of Winter Nelis farthest from the Williams' invariably bore least fruit. We have a report from a grower that in one year trees of Conference adjoining pollinator trees yielded better than those farther away.

The importance of suitable weather for pollination and fruit set, can be seen in Fig. 1, in which the years when the weather was windy and cold at blossom time are marked B. In five of the seven years thus classified as having ' bad pollinating weather ', the yield was less than 50 lb. per tree, and in the other two years, less than 100 lb. There is no definite standard for ' bad pollinating weather ' and the criteria used in Fig. 1 were wind above 10 to 15 m.p.h. with temperature below 50-55°F. during most of the blossom period, together with other weather conditions noted at the time.

Again, more information is needed ; but it seems that provision of plenty of pollinators, together with reasonable shelter is a good form of insurance, although, as with apples, the effects will doubtless be greater in some years than others.

' Blossom condition '

In some years blossoms are larger and ' bolder ' than in others, and there seems more than a suggestion that the smaller, weaker blossoms are less liable to set than the larger ones. The blossom condition appears to be a feature of the tree itself, and may be associated with nutrition, exhaustion of reserves by a heavy previous crop, weather conditions in the previous season, or other factors.

Fruit set

Fruit set largely depends on pollination conditions, but also on other factors. If even a relatively small amount of blossom sets well, a good crop can still result. Thus in Fig. 1, which shows the amount of blossom (based on a category record) as well as the yield, we see that in two years (1944 and 1951) the lowest blossom category still produced yields above 100 lb. per tree owing to good setting conditions. In 1958 detailed records indicated that branches covered with blossoms had fruits distributed singly on the spurs, whereas branches with little blossom set several fruits on fewer spurs ; and in each instance the total number and weight of fruit was much the same.

Fruit set can be affected by climate, pollinators, and probably ' blossom condition ' as mentioned above, and also by spray damage.

Spray damage

Recent investigations at East Malling show that Conference and Doyenné du Comice are susceptible to damage from mercury compounds. Leaf damage, in the form of chlorotic spotting, wrinkling and even defoliation has been traced to the use of phenylmercuric chloride (PMC), which is also used in mercurated lead arsenate, and other phenylmercuric compounds. Depending on the strength used and the time of application, a crop reduction of up to 80 per cent was caused. Furthermore in another experiment on Conference, mercury applied in 1955 had also the effect of reducing the number of fruit-buds in 1956. Other varieties on which leaf damage has been recorded are Laxton's Superb and Williams'. Some varieties may not be affected—but on present knowledge, the use of organomercurial fungicides on pears is not recommended. In the same investigation there was a suggestion that lime-sulphur applied pre-blossom, with dispersible sulphur post-blossom, reduced fruit set and yield.

Many growers have found that replacing sulphur and copper sprays with captan has led to remarkable increases in the yield of Doyenné du Comice.

Thus it appears that in the past much fruit has been removed by unrecognized spray damage, and careful attention must be paid to selection of safe routine sprays for pears.

Scion rooting

The yield of pears on quince can be seriously and permanently reduced by scion rooting, which can occur if the union is in contact with the soil. In general, such roots rapidly supersede the quince root system, and the tree becomes excessively vigorous and upright in habit, and produces less fruit buds with an increasingly meagre fruit set. Varieties differ in their readiness to form scion roots ; records of Conference doing so are very rare, but Comice and Williams' do so readily. Not all varieties react in the same way to scion rooting. While Pitmaston Duchess, Comice, and Williams' can be harmfully affected by it, it has been suggested that some other varieties, including Laxton's Superb, will not. If varieties are growing too weakly, encouragement of scion rooting will usually induce greater vigour. However, as pears are generally grown on quince in this country because it provides trees of more suitable size, of greater precocity, and better fruit size and quality than on pear, scion rooting is undesirable. It can easily be avoided by working at least 5 in. above soil level, and avoiding drawing soil up to the tree in the plantation. While scion rooting is worth keeping a look out for, it is probably not now a major problem.

Soil

Pears need a good soil, and pear on quince is found to grow well on some soils that would be considered too heavy or wet for apples. Very alkaline soils are unsuitable for pears. There is no evidence that soil is a major factor in variation in pear yields.

Age of trees

At East Malling there seems to be no evidence that pears on Quince A, B, or C, now 39 years old, are losing their cropping potential. The series of rather lower crops between 1947 and 1955 (Fig. 1) seems associated with tree overcrowding and poor pollinating conditions, rather than age ; for as soon as the trees were thinned, in winter 1955, yields rose sharply ; and in 1958 at 39 years old the trees have borne their highest yield so far.

It may be that cycles of poor weather conditions, which so far are not precisely defined either as to scope or duration, have given rise to the impression that yields are falling off. We have, however, had reports from growers that plantations, which previously had given disappointing yields for some years, cropped very well in 1958.

Pests and diseases

Modern spray techniques are generally adequate for control of insects ; but occasionally conditions favour the rapid build-up of insect populations leading to an epidemic. A serious outbreak of pear sucker may cause premature defoliation, fruit drop, and under-sized or mis-shapen fruit, and may also result in damage to fruit buds. The complete failure of a Conference plantation to crop in 1957 was attributed by the owner to a severe infestation of pear sucker in the previous autumn. Young orchards are sometimes damaged by the pear leaf midge, which badly distorts the foliage and possibly checks the growth of the tree in consequence. These insects are of sporadic occurrence, but during the last few years they have on occasion been mentioned as serious in certain orchards ; Conference is susceptible to both.

Damage to fruit buds by birds is serious in a few areas. Finches are the main offenders, and shooting or trapping have been recommended. It is important to carry out these operations before the attack develops.

Diseases are not commonly a major factor in the irregular cropping of pears. The routine measures for control of scab and canker are usually effective. Attention has recently been drawn to the widespread existence in pear orchards of certain virus diseases, which, though not preventing cropping, are likely to lessen the yield. Use of virus-tested material for planting new orchards will help to eliminate this danger. Virus-free Quince A rootstocks are available, and virus-tested mother trees of important scion varieties should be available shortly.

Practical conclusions

Pear growing has more stringent climatic demands than apple growing, and, if the averages are anything to go by, pears are likely to produce a smaller yield per acre than apples, except in the most favoured localities. Any apple grower who is considering planting pears to escape from overproduction of apples, should consider carefully whether his conditions are suitable. Some of the hazards, such as frost, wind, spray damage, and lack of pollination can be fairly well defined, and, within limits, avoided.

There seems no basic reason why more regular cropping than at present should not be obtained, in suitable areas ; but the solution to some of the problems will need further research, which may well be of a long-term nature.

We should welcome any further information from growers who can supply data of pear yields of the same plantations over a long series of years, together with details of the treatments applied.

Acknowledgements

Considerable investigations of certain aspects of this problem were made at East Malling some years ago by Dr. D. N. Srivastava and Dr. F. C. H. Gayner, and in preparing this paper we have drawn on their published work and that of many other authors, to all of whom we tender our thanks. We also thank the many growers who have supplied us with information.

Summary

Factors responsible for irregular cropping of pears are reviewed, with particular reference to the variety Conference. Major factors are frost, wind, and spray damage. Others include lack of pollination, bird damage, and scion rooting. More research is needed on many factors, including ' blossom condition '.

THIRTY-FIVE YEARS' RESULTS WITH SOME MALLING CLONAL APPLE ROOTSTOCKS

By A. P. PRESTON

The pioneer field trials of clonal apple rootstocks at East Malling are now more than thirty-five years old. Results from these long-term trials with Lane's Prince Albert, Worcester Pearmain, and Cox's Orange Pippin as scion varieties have recently been published in full in the Journal of Horticultural Science (Volumes 33 and 34). This paper briefly summarizes some of the main rootstock effects upon tree size and cropping recorded throughout this period.

Plot histories

Lane's Prince Albert.—This trial, covering two acres, was planted in January 1920 on a sandy loam of the Malling Series. Half-standard trees of Grenadier were planted as pollinators and half of these were removed in 1951 and the remainder in 1954. Some trees of Lane's were frameworked to Howgate Wonder to provide for pollination after the removal of the Grenadiers. All trees were spaced at 15 ft until some of the trees of Lane's were grubbed at 27 years of age. The trees were leader-tipped and spur-pruned. The plot was clean cultivated and there were no differential spraying or manurial treatments.

Worcester Pearmain.—This trial, covering 1¼ acres, was also planted in January 1920 on a similar soil and adjacent to the Lane's trial. Each row of Worcester alternated with one of Bramley's Seedling, the trees being 15 ft apart, until the 16th year when the Bramley's were grubbed and other Worcester trees were transplanted to their places together with trees of James Grieve to provide pollination. These transplanted Worcesters were grubbed in the 31st year and the spacing was thus increased to 21 ft. During the first eight years half the trees were unpruned (apart from initial heading back) and the remainder long spur-pruned, thereafter all trees were long spur-pruned with leader tipping becoming lighter with age until the twenty-sixth year when trees on the more vigorous rootstocks, such as M.XVI, were pruned by the renewal method. The plot has been under both grass and clean cultivation at different periods during the trial.

Cox's Orange Pippin.—This trial was planted in February 1922 and it covered 1½ acres on a sandy loam of the Malling Series merging into shallow and eroded phases of this Series. The Cox rows alternated with pollinator rows of Stirling Castle with the exception of the two central rows. The latter variety proved susceptible to the sprays then used to control fungal diseases and the trees were worked over to Worcester Pearmain. The trees were initially spaced at 12 ft apart, but were thinned in 1943 to 24 ft. They were spur-pruned with fairly hard leader tipping. The plot was clean cultivated until 1954 when wild white clover was sown and grass allowed to invade. Spraying trials to control apple scab were made an experimental issue on this plot from 1926 onwards but care was taken to ensure that pomological comparisons between trees on different rootstocks were not affected by the spray treatments.

Tree size

With all three scion varieties M.IX made the smallest trees and, ultimately, M.XVI made the biggest, but until the fifteenth year there were important changes in the relative order of rootstocks, especially in the semi-dwarfing and vigorous groups. During these early years, trees on M.VII were as large as those on M.II and trees on M.IV were as large as those on M.XVI. Trees on the different rootstocks, under all three scions, had settled down into their final relative order for tree size by the 15th year, after which there were no further changes (Table I).

TABLE I

ORDER OF ROOTSTOCKS FOR TREE SIZE AT 15 AND 35 YEARS OF AGE

	Trunk cross-sectional area*					
Lane's Prince Albert	IX	VII	IV	II	I	XVI
Worcester Pearmain	IX	VII	IV	I	II	XVI
Cox's Orange Pippin	IX	I	IV	II	XVI	

* Arranged in order of increasing size from left to right.

In the vigorous group there was a clear scion preference, trees of Lane's on M.I being larger than those on M.II whereas the reverse was the case with Worcester. Trees of Cox on M.I, normally classed as a vigorous rootstock, were weaker than those on M.IV. Many of the Cox trees on M.I were known to be on a shallow piece of soil and they behaved poorly in the seven severe summer droughts that occurred during the trial. These factors probably account for the poor behaviour of the Cox trees on M.I and this parallels the experience of growers using this rootstock on shallow soils in the drier parts of England.

Cropping

The total crop in bushels per tree up to 35 years of age, the heaviest mean crop and the year in which this was borne, are shown in Table II.

TABLE II

ACCUMULATED CROP PER TREE (BUSHELS)* AT 35 YEARS OF AGE. HEAVIEST CROP AND AGE AT WHICH IT WAS BORNE

Rootstock	Lane's Prince Albert			Worcester Pearmain			Cox's Orange Pippin		
	Total crop	Heaviest crop	Age	Total crop	Heaviest crop	Age	Total crop	Heaviest crop	Age
IX	33	2·1	33	45	2·7	27	25	2·5	26
VII ..	60	4·1	16	66	4·3	27	—	—	—
IV	95	6·5	27	101	6·9	27	42	4·0	26
I	101	7·0	27	92	6·5	28	28	2·6	26
II	92	6·6	33	105	7·2	27	59	6·4	26
XVI ..	117	10·2	27	122	9·3	29	62	7·4	26

* 1 bushel = 40 lb.

Over the whole period, with each scion variety, trees on M.IX carried least fruit and those on M.XVI most. Trees on M.IX were predominant during the early years for high yield but by the tenth year trees of Lane's and Worcester on M.IV overtook them and Cox trees likewise by the fifteenth year. Again a scion preference was shown with trees on M.I and M.II, trees of Lane's on the former rootstock cropping more heavily than those on the latter whereas the reverse was the case with Worcester.

The unpruned trees of Worcester cropped more heavily that the pruned trees and this effect persisted after all trees had been pruned alike from the ninth year. Leader tipping and spur-pruning was well suited to Lane's, a free cropping variety. The Cox trees, however, especially those on vigorous and very vigorous rootstocks, were pruned too hard by present-day standards and it is hardly surprising that trees on M.IX were the only ones to yield a total crop of a bushel of fruit per tree by the tenth year.

When some of the trees of Lane's and Cox's were grubbed, at 27 and 22 years of age respectively, their carcase weights were compared with their cropping performance. Trees of Lane's on the very vigorous M.XVI had yielded five times their own weight in fruit whereas those on the dwarfing M.IX had yielded 14 times their own weight. The Cox trees on M.IX had yielded eight times their own weight in fruit and those on M.XVI less than twice their own weight.

Crop relation to tree spacing

The different sizes of trees produced by clonal rootstocks covering a wide range of vigour affect economic distances of planting. Estimated yields per acre, based upon the accumulated crops at three periods during the trials and an estimate of the distances required by trees on six rootstocks, are shown in Table III. While trees of Lane's on M.XVI would be adequately spaced at 24 ft apart, under the conditions of these trials, trees of Worcester on the same rootstock and at the same spacing would have been over-crowded at 35 years of age. Again, on a deeper soil or in a wetter area Cox trees on M.IX and M.IV might not need more room than that shown in Table III whereas it is almost certain that trees on M.II and M.XVI would need wider spacing.

It should be emphasized that these figures are estimates, based upon the assumption that the yields would be the same at the distances given in Table III as they were at the uniform distances of the actual trials. Some growers may consider the average annual yields for trees on some rootstocks during the last ten-year period optimistic, for example, 400 bushels per acre for Cox on M.IX

TABLE III

ESTIMATED CUMULATIVE YIELD PER ACRE IN BUSHELS (40 LB.) AT APPROPRIATE SPACING FOR TREES ON DIFFERENT CLONAL ROOTSTOCKS

Rootstock	IX	VII	IV	I	II	XVI
Spacing (ft)	12	15	17	20	20	24
No. of trees per acre	302	193	150	108	108	75
Lane's						
10 years	**1,109**	1,013	956	596	453	345
20 years	4,937	5,640	**5,902**	4,465	3,523	3,133
30 years	8,229	9,539	**10,968**	8,642	7,470	6,716
Worcester						
10 years	**1,170**	762	863	497	478	328
20 years	4,538	3,850	**4,811**	3,227	3,281	2,169
30 years	10,253	9,607	**11,704**	7,668	8,532	6,323
Cox's						
10 years	**392**	—	142	99	97	20
20 years	**2,604**	—	2,332	915	1,638	864
30 years	**6,613**	—	5,351	2,508	5,140	3,523

and 570 for Worcester on the same rootstock, when compared with 350 and 525 bushels respectively for these two varieties on M.II. Bearing in mind the limitation of this method of estimating yields the figures are of interest and show that the order of rootstock based upon accumulated yields *per tree* (Table II) may be considerably modified if calculated on a *per acre* basis (Table III), quite apart from the possibilities of using more than one rootstock in orchard planning.

These classical rootstock trials, planted over 35 years ago, have demonstrated the value of clonal rootstocks in apple growing and they have paved the way for the breeding, selection and introduction of new and improved clones. The latest results of trials comparing the newer Malling-Merton rootstocks with some of the older Malling clones and using a much lighter method of pruning are reported on p. 47.

Summary

The main results over a 35-year period are given for apple trees of Lanes' Prince Albert, Worcester Pearmain, and Cox's Orange Pippin on the following six clonal rootstocks : M.IX (dwarfing), M.VII (semi-dwarfing), M.IV (moderately vigorous), M.I and M.II (vigorous), and M.XVI (very vigorous).

FIRE-BLIGHT DISEASE OF PEAR

By J. E. CROSSE, MARGERY BENNETT and CONSTANCE M. E. GARRETT

During 1958 fire-blight was identified for the first time in Britain. This destructive disease of pear and apple is caused by the bacterium *Erwinia amylovora*, and derives its name from the fact that badly affected trees appear as if they have been swept by fire. Fire-blight is a native of North America where there are records of the disease going back to the 18th century. It probably occurred originally on wild hosts and spread to cultivated apple and pear varieties when these were introduced from Europe. The disease is present in the U.S.A. wherever apples and pears are grown and in some of the warmer and more humid areas of the eastern States it is still a major factor limiting the successful cultivation of these crops. Fire-blight has been previously suspected in various European countries but none of the reports has ever been confirmed. Outside North America it is known for certain only in New Zealand, where it first appeared in 1919 and in the next ten years spread to most fruit growing areas of the Dominion.

The disease was first observed in this country in the late summer and autumn of 1957, when pear trees of the variety Laxton's Superb on five Kentish fruit farms were found to be dying from extensive cankers present on the stems and branches. When the full extent of the trouble became apparent, research was immediately concentrated on the problem at East Malling, in collaboration with the N.A.A.S. and the Plant Pathology Laboratory, Harpenden. As a result it was proved that the disease was caused by a bacterium, subsequently indentified as the fire-blight organism, *Erwinia amylovora.*

During 1958 the disease continued to spread in some of the affected orchards and as a result of surveys carried out by the N.A.A.S., and reports received from individual growers, the disease has now been identified on twelve farms in Kent, located in the Maidstone, Rochester, Wrotham, Swanley, and Sevenoaks areas and on one farm in the West Midlands. Four of the Kentish outbreaks were new in 1958, and occurred not far from farms where the disease was present in 1957.

In both 1957 and 1958 the disease has been outstandingly serious on the pear variety Laxton's Superb. In 1957 for example, 80 per cent of the trees in one orchard were killed or badly damaged, while in another locality, a small mature orchard of this variety was virtually destroyed by the disease during 1958. A bad attack on Fondante de Thirriot was seen on one farm in the Rochester district in 1958 ; all other varieties have so far escaped the worst effects of the disease although a few infected trees of Conference, Williams' Bon Chrétien, Dr. Jules Guyot, Bristol Cross, and Comice have been found in some localities.

Disease cycle

Fire-blight attacks trees only when they are actively growing. Infection begins in the blossom and spreads rapidly into the branches forming cankers. These continue spreading until late in the season and may eventually reach the trunk of the tree. Cankers remain dormant over the winter, but some of them become active again next spring. In these ' holdover ' cankers, as they are called, the bacteria survive the winter and come to the surface in droplets of ooze at about the time the first blossoms are opening. They are carried to the flowers by rain and insects and set up the first or primary blossom infections. Rain and pollinating insects then carry the bacteria to other blossoms here and there through the orchard and in this way the disease is rapidly spread. In Kentish orchards most of this spread has occurred in late or summer blossoms, possibly because conditions were then more suitable for infection than in the spring. In the U.S.A. blossom infection is favoured by high humidity and fairly high temperatures. High humidity tends to lower the concentration of sugars in the nectar to a level at which the bacteria are able to multiply. The tendency for Laxton's Superb to produce plenty of late blossom may partly account for the concentration of the disease in this variety.

Shoots and fruits are sometimes infected during the summer and infection may spread from these into the branches in the same way as from blossom.

Symptoms of disease

Blossom and branches

Infected blossoms turn black (Fig. 1) and at this stage appear not unlike the bacterial blossom wilt with which many growers are already familiar. Bacterial blossom wilt is caused by an unrelated bacterium called *Pseudomonas syringae* and this usually attacks the spring blossom in cold, wet weather. It may kill the fruiting spur and exceptionally invade the branch forming cankers, but its spread is

soon checked when the trees start to grow and the cankers usually remain small, often no bigger than a half-crown. The fire-blight organism, on the other hand, spreads rapidly down spurs and lateral twigs into the main branches and continues unchecked throughout the summer (Fig. 2). Leaves in the affected area of the branch lose their shine and begin to turn black from the margin inwards (Fig. 3). The presence of a small patch of such leaves on the branch of the tree is usually the first obvious sign of the presence of fire-blight. When the branch is invaded the surface of the bark turns a grey-black colour, which contrasts strikingly with the normal brown of healthy bark. If a slicing cut is made in the diseased area of a branch it will be found that the inner layers of the bark are still white, but overlaid by a thin, wet-looking, dark brown layer, immediately under the surface of the bark (Fig.4). This appearance is quite characteristic and is a very useful diagnostic feature. In older parts of branch cankers the bark becomes drier and is stained brown right down to the wood. As the cankers progress down the branch, more and more of the leaves begin to show the marginal browning, and eventually turn completely brown. It is at this stage that the typical ' scorched ' appearance becomes apparent (Figs. 5 and 6).

When the canker reaches the trunk or larger branches of older trees the diseased area is not so readily seen from the surface because of the thickness of the bark, but the extent of the canker can usually be explored by cutting with a knife.*

At any time from August to November cankers cease to spread, cracks are formed at the margin of the healthy and diseased parts, and the outline of the canker can then be clearly seen (Figs. 7 and 8). Cracking does not invariably occur and in these cases the outline of the canker can usually be seen as a depressed, darker area under the bark. Longitudinal cracks are sometimes formed earlier in the season on the cankered area itself and in hot humid weather these may secrete a sticky ooze.

When dormant cankers are cut during the winter they have a different appearance from the active cankers described above. The bark is dry and stained brown to the depth of the wood and the superficial layers of the corky bark tend to wrinkle and flake off in pinkish scales.

Overwintered cankers become active again in spring or early summer and the bacterium invades healthy bark along the margins of the cankers. Newly invaded areas are similar in appearance to active summer cankers, except that the outer layers tend to be stained a foxy-red, rather than dark brown. Although cankers originating from the infection of a single blossom are usually extensive, occasionally the infection is sealed off soon after entering a branch and the cankers remain small (Fig. 9). This was particularly common in the West Midlands outbreak, where the trees were not very vigorous.

Shoots and fruits

These may be attacked at any time during the growing season. Succulent, fast growing shoots, e.g. water shoots, are particularly susceptible. The bark of the shoot first turns light brown (Figs. 2 and 10) and under humid conditions exudes a whitish bacterial ooze. This turns amber after exposure and is washed over the shoot by rain, giving it an oily appearance. The leaves on infected shoots remain green at first, but later, as the shoot turns black, they begin to wither. Infection may spread into branches from shoots in the same way as from blossom, but this is relatively uncommon.

On badly diseased trees one or two infected fruits may occasionally be seen at any time from fruitlet stage to picking. They appear dark olive-green at first (Fig. 11), but become oily-brown and wrinkled, and eventually turn black. At this stage they look rather like dried prunes (Fig. 12).

Host range of the fire-blight organism in North America and New Zealand

In the U.S.A. all commercial pear varieties are susceptible to fire-blight including the widely grown Bartlett (Williams' Bon Chrétien). Apple varieties show a greater range of resistance and generally the disease is less severe, but no variety is immune. The symptoms on apple are essentially the same as those described except that the diseased parts remain brown and do not turn black. Under natural conditions in the U.S.A. fire-blight seriously affects only pear, apple, and quince but it also attacks several plants of the Rose family, particularly those most closely related to pear and apple, e.g. hawthorn, cotoneaster, fire-thorn (*Pyracantha*), and mountain ash. In New Zealand, hawthorn is frequently attacked and the presence of untrimmed hedges bearing blossoms is believed to have been important in the spread of the disease in that country.

Discussion of control measures in North America and New Zealand

The first thing we must do in this country is to try to eradicate the disease before it becomes too widespread, and active steps have already been taken in this direction. If these efforts fail, and their

* Knives used for cutting active cankers for identification must not be used on healthy trees until after they have been thoroughly disinfected with an antiseptic, otherwise the healthy trees may become infected.

Fig. 1

The earliest stage of the disease showing recently infected summer blossoms of the pear variety, Laxton's Superb. Note blackened flower trusses.

Fig. 2

The infection has spread from a blossom on a lateral twig (right of the photograph) into a branch and two shoots. The leaves on the lateral twig are turning brown.

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FIG. 3

Group of leaves with marginal browning. This is one of the first obvious signs of the disease in an orchard.

FIG. 4

Part of a newly diseased branch, with leaves removed, cut to show the internal appearance of an active canker. The wood and deeper layers of the bark are still white, but are overlaid by a thin brown layer of diseased bark. The surface of the bark in the uncut area is grey-black in colour.

FIG. 5

A later stage of the disease ; the infection has entered a main branch and is spreading rapidly. Patches of brown leaves are present and the branch is beginning to show a typical scorched appearance. The surface of the bark is grey-black in colour.

FIG. 6

The final stages of the disease ; two lateral branches were cut off earlier in the season, but too late to prevent the infection spreading into the trunk. The centre of the tree has been destroyed and only one branch, originating low down on the trunk, survives.

FIG. 7

A small dormant canker on a branch, photographed in the autumn. The canker has stopped spreading and cracks are appearing at the boundary between the healthy and diseased bark. The surface of the bark is wrinkled

FIG. 8

The margin of a dormant canker, with cracks separating the diseased area (*top*) from the healthy bark (*bottom*). Note the finger-like protrusion of the canker

A small canker on a branch (*right*) originating from an infected summer blossom at the end of a shoot.

FIG. III

A shoot artificially infected in the laboratory showing droplets of bacterial ooze. In the field this ooze washes over the surface of the shoot giving it an oily appearance.

FIG. 11

A fruit of a potted tree of Laxton's Superb pear, seven days after artificial infection with bacteria from a naturally occurring canker. The fruit has a water-soaked, olive-green appearance and droplets of bacterial ooze are present on the surface.

FIG. 12

A black wrinkled fruit, in the later stages of infection.

success depends largely on the conscientious co-operation of every fruitgrower, then control measures of the kind described below may have to become a routine practice in commercial pear orchards in some parts of Britain.

Except in areas where climatic conditions and other factors are overwhelmingly in favour of the disease, fire-blight can be controlled, but as with many other bacterial diseases this is an exacting and tedious business. Measures devised in the U.S.A. after many years experience can be broadly divided into two groups :

1. Direct measures, aimed at preventing infection of blossoms, or removing infections before they spread too far.
2. Indirect measures concerned with controlling growth of trees in such a way as to make them less susceptible to the disease.

Direct measures

As mentioned earlier, bacteria survive the winter in ' holdover ' cankers. These are the main, and probably the only source for infection of blossom in spring, and it is generally agreed by American workers that the removal and destruction of cankers or cankered trees before the blossoms open in spring is the most important single measure in control. Because it is not always possible to ensure that all cankers are removed from a diseased orchard, blossom sprays are used in some areas of the U.S.A. as a further protection against the disease. These are applied during the spring when 25-30 per cent of the blossoms are open and again 7 and 14 days later. Bordeaux mixture (2:3:100) has proved one of the most effective materials for this purpose, but it tends to cause russeting of the fruit. This difficulty has to some extent been overcome by growers in California by using lower strength Bordeaux mixtures, e.g. $\frac{1}{2}$:$\frac{1}{2}$:100, without, apparently, any loss in disease control. In recent years the antibiotic streptomycin has been tested as a blossom spray in various parts of the U.S.A., and has given good results at concentrations ranging from 30-100 parts per million. There is some evidence however that it is less effective than copper sprays at lower temperatures, and in New York State it is recommended that it be used only when temperatures during the blossom period are expected to reach 70°F.

It should be emphasized that these spray programmes are aimed at the control of infection during the spring blossom period. They are less likely to be effective against widespread infection of late or summer blossoms which has been one of the features of the Kentish outbreaks.

The last line of defence in fire-blight control consists of inspecting trees at regular intervals after petal-fall and cutting out any infections which have escaped the above measures, before they have spread too far. Where the infection has already entered a branch it is recommended that cuts should be made at least 12 in. below the edge of the diseased area, and that knives used for this purpose should be thoroughly sterilized with a strong antiseptic after each cut. The cuts are treated with white lead paint or a coal-tar creosote preparation to prevent re-infection through the open wounds. As an alternative to cutting out, branch cankers in an early stage of development are sometimes treated with a special paint. This is applied to the surface of the bark in the diseased area and has the effect of killing the bacteria in the tissues beneath. These paints are only of limited value, however, and are extremely damaging if they are allowed to contact open wounds in the tree.

Indirect measures

Fire-blight is usually worst on vigorous trees, and indirect control measures consist of orchard managements designed to prevent rapid and succulent growth during the spring and early summer. The practices adopted depend very much on individual circumstances and no details can be given here. One of the most important factors, however, is to avoid heavy dressings of nitrogenous fertilizers.

How and when was fire-blight introduced into Great Britain ?

We can only speculate on these questions at present. When diseases are introduced into new areas they do not necessarily assume an epidemic form immediately on arrival. Hence fire-blight may have been present in this country before 1957 ; the distribution of outbreaks in 1957 viewed in the light of spread during 1958 tends on the whole to support this view. Local evidence is not very clear on this matter, but it is quite possible that small cankers or occasional die-back caused by fire-blight may have been overlooked, or attributed to other causes, e.g. the apple and pear canker fungus *Nectria galligena*.

The way in which fire-blight reached this country is even more obscure. In the past the introduction of disease into new areas has nearly always been the result of importing infected or contaminated plant material, e.g. seed, stocks, budwood etc. Distribution of a disease *within* a new area can also take place in the same way. As far as the present case is concerned we have no evidence either way

on this problem, but it may, perhaps, be stressed that there are fairly strict regulations nowadays to guard against introductions on imported plant materials. It has been suggested that fire-blight may have been introduced on imported fruit boxes. The chance seems remote, but it cannot be entirely disregarded.

Future development in Great Britain

Although varieties like Conference and Williams' have so far escaped the worst effects of the disease it does not necessarily follow that they will continue to do so. Williams' is one of the most susceptible varieties in the U.S.A., and it has not shown any marked resistance in our inoculation experiments. As mentioned earlier, no varieties of commercial value escape the disease in the U.S.A. and experience there is that the disease may be severe on one variety one year, while in the next year another variety may suffer. This difference is apparently related to time of blossoming, weather conditions favourable for infection, and growth conditions of the tree. Apart from the risk on other pear varieties, there is also the considerable danger of fire-blight spreading to apple and to hawthorn. In this connexion it is worth mentioning that both hawthorn and apple (Cox's) shoots and fruits have been successfully infected in this laboratory using bacteria originally isolated from Laxton's Superb pear.

Looking on the brighter side, it is still questionable whether fire-blight would ever assume the proportions in this country that it has elsewhere. Maritime climates with relatively cool summers do not favour the disease and for this reason it has never been as serious in the Pacific Northwest and areas round the Great Lakes as it has in other parts of the U.S.A. Neither, we are told, has the disease become quite the problem in New Zealand as was at first feared. In the face of the devasting outbreaks in Kent during 1957 and 1958, these arguments may not sound very convincing, but it should be pointed out that we have not so far been able to do very much to check the disease. Once control measures are instituted, therefore, the whole position may be considerably changed. This leads us on to consider the future course of action. From what we have already said about the disease, it will be clear that the immediate problem is to remove all overwintering sources of infection, i.e. ' holdover ' cankers, from affected orchards, before the blossom opens next spring. Under the provisions of the Fire-blight Disease Order (Destructive Pests and Diseases Act), which came into operation on 6th November, 1958, fire-blight has been made a notifiable disease. During the winter 1958-9 an attempt is to be made to grub and destroy by fire all diseased trees in affected orchards. The effects of these measures will not be apparent until summer 1959. They are expected drastically to reduce the amount of infection in the orchards concerned, but how far they will succeed in eradicating the disease remains to be seen. It is extremely difficult to be certain that all cankers are removed, or that alternative sources of infection are not already present on other hosts, i.e. hawthorn or apple. We must therefore anticipate reappearance of the disease in 1959, although possibly on a very reduced scale. It is of great importance to the future success of the campaign that all cases of fire-blight in 1959 should be notified immediately to the N.A.A.S. as soon as they are observed. Growers are strongly urged, therefore, to study the accompanying photographs and to make themselves familar with the symptoms of fire-blight so that they can recognize it at the earliest possible stage. They are also advised to keep an eye on apple and hawthorn, especially from blossom time onwards. The success of the campaign against this disease will, in the last resort, depend on the fruitgrowers.

Summary

A serious bacterial disease of pear, first observed in Kentish orchards late in 1957, has been identified as ' fire-blight '. Details are given of its disease cycle and the symptoms are described and illustrated. Control measures in New Zealand and North America, where the disease has been known for many years, and the origin and possible future developments of the disease in Great Britain, are discussed.

RESISTANCE TRIALS OF SOME APPLE ROOTSTOCK VARIETIES TO COLLAR ROT *(PHYTOPHTHORA CACTORUM)**

By G. W. F. SEWELL and J. F. WILSON

The soil-borne fungus, *Phytophthora cactorum* (Leb. and Cohn.) Schroet., can invade and rot the bark tissues of certain apple rootstock and scion varieties, and may, if the infection girdles the crown or collar region, cause death of the tree. Most rootstock and scion varieties grown in England, however, are fairly resistant to attack by this fungus, and indeed, only Cox's Orange Pippin has been found to be seriously affected.

While it is now known the *P. cactorum* is a common cause of crown and collar injury, it must be emphasized that not *all* such damage is due to this pathogen. Once *P. cactorum* has been diagnosed as the cause of tree death, certain measures can be taken to reduce the chance of further attacks, and these have previously been described.† Such measures, however, are rarely completely successful ; moreover the initial attack of the fungus may be rapid and severe, causing the subsequent widespread death of trees. Field observations indicate that the likelihood of infection of susceptible scion varieties is closely related to the distance between their tissues and the soil, and that under English orchard conditions, Cox tissues (for example) if raised 12 or more inches above soil level would be almost completely free from the disease. The most promising approach to this problem therefore lies in *avoidance* of the disease by careful planning of future plantations—particularly if these are to be of Cox's Orange Pippin. The chances of direct invasion of susceptible scion tissues from the soil would be greatly reduced by working the scion variety well above soil level either directly onto a resistant rootstock or onto a resistant ' stem building ' variety. Since the efficacy of this method of avoiding the disease will depend on the resistance of the rootstock, the investigations described below were undertaken to determine the relative resistances of a range of East Malling rootstocks to as many isolates of the disease organism as was practicable.

Methods of testing

Two methods of testing were used in these experiments :

(a) The stems of one- and two-year-old, unworked rootstocks were inoculated by inserting a disc of agar culture of *P. cactorum* into the bark to the level of the cambium. The inoculation wound was then sealed with adhesive tape. The results of these inoculations were later recorded by measuring the vertical length of the rotted bark, after removal of the external corky layer. Eight isolates of *P. cactorum* were used, and the experiments were repeated in two consecutive years.

(b) Short lengths of stems of several rootstock varieties, inoculated by the method described above, were stood in one inch of water and stored for three weeks under standard conditions after which the extent of rotting was recorded.

These two methods gave similar results.

Results

Data from inoculation experiments carried out in 1956 and 1957 are summarized in Table I where the rootstocks are arranged in order of average resistance, and, for convenience, are divided into three resistance classes.

TABLE I

ROOTSTOCK VARIETIES ARRANGED IN ORDER OF AVERAGE RESISTANCE TO SEVERAL ISOLATES OF *P. CACTORUM*

Resistance	Rootstock Varieties
High ..	M.VII ; MM.106 ; Northern Spy ; MM.111; M.IX ; M.XXV ; M.II ; MM.109 ; MM.104
Intermediate	M.I ; Crab C
Low ..	M.26 (3436); M.XIII ; M.XVI ; M.XII

* This bulletin is based on a paper published in the *Journal of Horticultural Science*, **34**, 51-8.

† *Rep. E. Malling Res. Sta. for 1956*, 168-9.

In assessing these results it may be found helpful to use M.II as a standard. This variety has consistently shown high resistance in the field under various soil conditions, as well as in extensive inoculation tests. Thus, MM.111, MM.106, MM.109, M.VII, M.IX, M.XXV and Northern Spy all showed high resistance comparable to that of M.II and all of these except MM.111 occasionally showed an even greater resistance than M.II. M.VII and MM.106 showed exceptionally high resistance in all tests. MM.104 was generally similar to M.II, but was of low resistance to one particular isolate of the disease organism.

The rootstocks included in the ' Intermediate ' group varied considerably in their resistance to different isolates of *P. cactorum* and also under differing test conditions. M.XII, M.XIII and M.XVI exhibited very low resistance in nearly all the tests.

It should be pointed out that the stem inoculation method used in these tests provides a measure only of the inherent resistance of the rootstock varieties, and does not necessarily reflect their *liability* to infection in the field, which may be influenced by other factors.

The five rootstocks, MM.104, MM.106, MM.109, MM.111 and M.XXV, which were recently released for commercial propagation are of considerable promise in that they frequently show greater resistances than the Malling rootstocks which they may eventually replace.

The feasibility of working resistant rootstocks at a height of 12 in. is at present under trial, but since every extra inch that they are worked above ground level lessens the risk of infection of susceptible scions, it follows that the modern practice of budding at least 5 in. above ground level (recommended also for avoidance of scion rooting) is safer than the older practice of budding at 2 in. or even less.

Summary

Some aspects of the control of collar rot are briefly discussed. Special reference is made to the possibility of avoiding this disease in future plantations (especially of Cox's Orange Pippin) by high-working scion varieties onto resistant rootstocks. Experiments designed to determine the relative resistances of some East Malling rootstocks are described and the results given.

RESEARCH ON HOP VIRUS DISEASES AT EAST MALLING

By J. T. LEGG and P. J. ORMEROD

THE SPREAD OF NETTLEHEAD

As long ago as 1894, nettlehead formed the principal subject at the first hop conference at Wye College. It is still one of the most serious problems of hop growers in England despite considerable research. Nettlehead is caused by a virus, but as the way in which it is spread is unknown and the severity of individual outbreaks cannot be predicted, no special control measures can yet be recommended.

The usual rate of spread has been estimated as a 2-5 fold annual increase but in the initial phase of an outbreak the rate may reach 10-20 fold for one or two years. The exposure of hop plants for monthly periods in a plantation has shown that natural transmission of nettlehead can occur during April, May, and June.

Viruses may be artificially transferred from an infected plant to a healthy one by grafting or by inoculation with sap, but under natural conditions they are usually spread by insects, known as vectors, or less frequently by some agency in the soil. The distribution of nettlehead suggests that the virus may be spread by an insect, although there is also some evidence that it might be soil-borne. There is no evidence that natural spread is by the mechanical transfer of infected sap. Research was therefore concentrated at first on finding the insect involved, by studying the distribution of affected plants, and by direct attempts to infect test plants. The results obtained were conflicting, and it is necessary therefore to consider separately the evidence for transmission through the soil and for spread by a mobile insect agent.

Evidence of soil transmission

Diseased hop plants are sometimes concentrated on sites of former hedgerows, ditches, and grassland and also in restricted areas of apparently uniform plantations.

This uneven distribution in a plantation may persist after complete grubbing and replanting with healthy stocks. In one instance, it recurred in the same area after the land had been planted with other crops for ten years. There is no environmental explanation of these localized outbreaks although in the West Midlands, Tolhurst of Long Ashton found evidence that they may be correlated with certain soil conditions. The simplest explanation, however, is that the virus has persisted in some way in the soil. Several soil-borne viruses are known, and most of these are readily detected by growing healthy plants in soil taken from around naturally infected plants. This does not happen with nettlehead ; in one outbreak recorded for seven years none of the 65 cuttings replanted immediately after grubbing diseased plants have become infected.

Furthermore, in experiments at East Malling, 100 hop plants were grown for three to four years without developing symptoms in soil taken from around nettlehead infected plants. The test plants used were planted both in association with, and isolated from, infected plants and also under waterlogged conditions. Another experiment is in progress under insect-proof conditions, in which 60 plants of the very sensitive variety Early Prolific have been grown for two years in soil from a nettlehead site ; none has yet developed nettlehead.

In another experiment 20 large pots, plunged in the ground, were each planted with 8 healthy Fuggle hop plants and 1-3 nettlehead-infected plants in unsterilized potting compost. During three years 8 test plants, distributed among 5 pots became infected, but, as these plants were growing in the open, infection above the ground remains a possibility.

In the light of these experiments it seems unlikely that the virus is soil-borne. It is still possible, however, that the virus may be widespread in soils of hop fields but that for some unknown reason hop plants seldom become infected.

Evidence of insect transmission

In most outbreaks, particularly in young hops, the first plants to show symptoms are scattered within the plantation. This sort of distribution, which may persist for several years, suggests that the virus is being spread from a host plant outside the plantation rather than from infected hop plants within it. The pattern may change after five to ten years and diseased plants occur in groups, indicating that either the virus is then spread from a source inside the plantation or a change has occurred in the insect vector's behaviour. If the latter is the explanation, the change may occur as increased growth of mature plants facilitates movement of insects among neighbouring plants.

Sometimes outbreaks are found near the edge of plantations, particularly if they are bordered

by tall hedges or large trees. A detailed study of two of these outbreaks has provided additional evidence of an outside source of the virus. In the first, which was bordered by a tall hedge, the plants in the two rows nearest the hedge remained healthy, while many of those in the next six rows were infected. At another site where a hedge had been cut down, most of the diseased plants were in the outside row of hops. Thus the tall hedge appeared to have ' protected ' the plants nearest it and most of the infection occurred at about the distance that air-borne insects would tend to fall-out from a wind blowing over the hedge, whereas the low hedge had no such effect and may have provided an alternative source of the virus, the transmitting insect, or both.

Tests with insects, mites, and eelworms

Most plant viruses are transmitted by insects, a few by mites, and at least one by eelworms. Most of these small animals that transmit viruses feed by sucking plant sap, but transmission is not just a simple transfer of infective sap and may not be achieved unless certain critical conditions are fulfilled. The behaviour of these animals is therefore important in determining the amount of virus spread in the field, and in experiments a wide range of feeding conditions should be examined.

At the beginning of our investigations all the insects and mites commonly found on hops were tested but none transmitted the virus. More than a hundred species of these animals have, however, been recorded on hop plants, and the scope of the experiments was expanded to include some of the rarer species. They were collected from hops in nettlehead outbreaks and either given a limited feed on a nettlehead-infected hop plant and then transferred to a healthy test plant, or were allowed to move freely and feed on groups of healthy and infected plants. In this way over 6,000 insects, mites, and eelworms were tested without success, although particular attention had been given to those present at the time nettlehead is known to spread (April to June). All these failures are consistent with the view that transmission is being effected by a mobile insect or mite from outside the hop garden ; the distribution of diseased plants in some outbreaks also supports this view. An additional survey of insects showed that many more aphid and leafhopper species are found within hop plantations than have been recorded actually feeding on hop. Undoubtedly the occurrence of most of these additional insects was fortuitous but some of them may occasionally feed on hop plants. Similarly in other groups of insects and mites there may be species that feed only occasionally on hop. Collections of insects and other small animals were therefore extended to include those from hedgerows and from weeds growing in hop plantations and on the headlands. These animals were tested collectively in the groups ; (1) aphids, (2) leafhoppers, (3) plant bugs, (4) beetles, (5) soil fauna, and (6) all other insects and mites. Some test plants from each group were infected but in view of the failure in previous tests, it seems improbable that nettlehead virus was transmitted so readily by a wide range of animals, especially as where several vectors are known for a virus, the insects that transmit it are quite closely related. It is more likely that the virus was transferred by leafhoppers which escaped from their cages and fed on the ' wrong ' test plants.

Leafhoppers able to transmit viruses have been known since the beginning of this century, but it is only in the last few years that leafhopper-transmitted viruses have been identified in western Europe and England. The viruses transmitted by leafhoppers cause similar diseases and have been classified as the ' yellows ' group, to which nettlehead would seem to belong on the basis of its symptoms. Hop plants did not become infected, however, when subjected to leafhoppers found either on hop or on weeds growing near hops and tested after feeding on nettlehead-infected hop plants.

At this stage in the investigation two leafhoppers, *Euscelis plebejus* (Fall) and *Aphrodes bicinctus* (Schr.), were found to transmit viruses in strawberry, clover, and many other weeds. Attempts were made to transmit nettlehead virus with these two species from hop to hop, and also to see if one of the newly recognized clover viruses was the cause of nettlehead. In these tests, two hop plants developed nettlehead symptoms after being subjected to leafhoppers transferred from an infected clover plant ; also one clover plant developed typical disease symptoms after it had been united to a nettlehead-infected hop plant by the parasitic plant, dodder. Despite considerable repetition, however, neither result has yet been confirmed.

Although conclusive information on how the virus is spread has not yet been obtained either from these insect tests or from studying the disease in the field, certain deductions can be made. The repeated failure to transmit the virus with insects commonly found on hops suggests that these are not the vectors. This is also supported by circumstantial evidence since the widespread use of systemic insecticides has markedly reduced the population of these insects and mites in hop plantations but has not reduced the spread of nettlehead. This also suggests that the transmitting agent is an animal which breeds and acquires the virus from some other host plant and then carries it to hop. Furthermore, the occasional fluctuations in the numbers of newly affected plants suggest that the animal carrying the virus comes from outside hop plantations and that the invasion of hops is influenced by variable environmental factors.

Disease control

It is obvious from the present knowledge that although specific control measures cannot be recommended there are some sensible precautions that can be taken.

Perhaps the most significant fact is that ' cuttings ' used for replanting after grubbing diseased plants are not especially liable to infection. Thus a policy of grubbing and replanting will probably prolong the life of a plantation. This has been demonstrated in a trial (Fuggle N) in which after seven years there are 75 nettlehead plants in plots where diseased plants have been left, and only 18 (the newly infected plants) in plots where they have been rogued. In this trial, however, the grubbing of diseased plants has not had a consistent effect on the rate of spread, and only in one year (1957) were there more new infections in the ungrubbed plots (30 in the ungrubbed as compared with 8 in the grubbed). The evidence from commercial plantations on this subject is not so good ; for instance in five plantations of Brewer's Gold, which have been rigorously rogued, the incidence of disease is declining, but substantial parts of two plantations (Fuggle and Early Fuggle) have been rendered uneconomic despite such a policy. Thus although roguing usually prolongs the life of plantations it may not always be successful in reducing the rate of infection.

Since nettlehead is mainly confined to the variety Fuggle it may be advisable to replant badly affected plantations with a less susceptible variety. Bullion is probably the best alternative although in one field trial it was more susceptible than Fuggle. The breakdown of one stock suggests that the freedom of this variety from nettlehead may not be due to an inherent character, but may depend on some other factor which may vary from plantation to plantation.

THE EFFECT OF SPLIT LEAF BLOTCH ON THE YIELD OF HOPS

Plants with symptoms of split leaf blotch can be found in most Fuggle hop plantations, and often more than half of the plants are visibly affected. It is, however, difficult to assess the extent of infection because infected Fuggle plants do not produce symptoms every year. When they do, there is considerable variation in the incidence and severity of leaf symptoms and the amount of stunting in different plants.

Affected Fuggle plants can often be detected early in the spring (March-April) when instead of the usual bushy growth of numerous stems from a healthy crown, only a few stems develop, and these are either stunted or, if of normal length, they bear only a few small leaves. Early in June irregular areas on the young leaves turn pale yellow, then translucent and finally necrotic ; the continued expansion of the leaf causes distortion and often tearing of the leaf blade.

The growth of affected plants is retarded ; this affects not only the main stems (bines), but also the lateral shoots on which the hops are borne. These plants continue growing after normal ones so that by the end of July it is difficult to distinguish between them.

Despite the irregular expression of symptoms in Fuggle plants, Keyworth was able to confirm by graft transmission that a virus caused the more severe forms, i.e. vigorous plants with some leaves showing extensive oily spots, distortion, and necrosis, and stunted plants also with these symptoms. The milder form with occasional oily blotches on leaves was not proved to be a virus disease because this symptom occurred on the ungrafted control plants. The condition of Fuggle seems to have deteriorated, as there are now no selected clones that have remained completely free from the severer leaf symptoms and it must therefore be presumed that all these clones are at least partially infected.

The importance of this is probably not fully recognized. It has been known for many years that plants severely affected by split leaf blotch produce a small crop, but no measurement of this reduction had been made until recently. In two field trials (1955 and 1956) the yield from Fuggle plants showing symptoms of split leaf blotch was only half that from symptomless plants, the obviously diseased plants yielding at the rate of 5·3 cwt. per acre compared with 10·1 cwt. from those apparently healthy.

Since Fuggle plantations account for about 70 per cent of the English hop acreage, the prevalence of split leaf blotch in this variety must cause a considerable loss to the industry. As there are as yet no completely healthy selections of Fuggle available, the only practical control measure is to rogue-out all plants showing split leaf blotch symptoms ; this procedure may be economic only when the incidence is low (say below 10 per cent). This emphasizes the importance of planting stocks that are as free as possible from disease and these can be obtained under the Ministry of Agriculture's certification scheme. An additional advantage of using these sets is that they invariably ' take ' well, whereas only about 60 per cent will grow when the sets are infected with split leaf blotch.

Little is known about the effect of split leaf blotch on varieties other than Fuggle. Symptoms are occasionally seen in Golding and Golding Varieties, particulary Bramling, but rarely to the same extent as in Fuggle. In the new varieties, symptoms are very rare, but it is not known whether this is due to immunity or, as experiments in progress suggest, to tolerance to the virus. If they are tolerant then an attempt must be made to determine whether the latent infection reduces cropping capacity.

Summary

Evidence on the mode of spread of nettlehead is conflicting ; the work reviewed suggests either that the virus is spread by a mobile insect or mite that only occasionally feeds on hop, or that the virus is soil-borne.

No decisive control measures can be recommended but the removal of affected plants followed by replanting can be of great value in prolonging the economic life of a plantation.

The symptoms of split leaf blotch are described and particular attention is drawn to the 50 per cent reduction of yield from affected plants of the variety Fuggle.

NOTES ON THREE NEW WILT-TOLERANT HOPS*

By J. F. WILSON

After satisfactory reports had been received on the initial brewing trials of the wilt-tolerant Wye varieties Keyworth's Midseason (OR55) and Keyworth's Early (OJ47), 22,000 sets were distributed in 1949 and production, especially of OR55, increased rapidly. Later, however, many brewers tended to avoid these varieties, a situation which certainly could not have been forecast from the initial brewing-trial results. Over-production followed, and new tolerant varieties became urgently needed. Whitbread's Golding Variety (1147) together with the Wye variety Bramling Cross (OT48) have partly met this need, but as neither is an ideal substitute for Fuggle, over-production of both is likely.

New varieties from the joint Wye-East Malling breeding project, which is aimed at producing a ' tolerant-Fuggle ', cannot be available in bulk before 1965 ; in the mean time, the Research Station has recently released to specialist hop propagators three varieties which were by-products of a breeding programme started by W. G. Keyworth in 1944 for the production of wilt-tolerant males. These varieties, previously known as D1, D3, and J2, have now been named *Density*, *Defender*, and *Janus* respectively, and small quantities of sets should be available from the propagators from the winter of 1959-60 onwards.

Farm trials

The new varieties were first tried out commercially on ten small plots on ' wilt-farms ' in various localities. All aspects of management, including harvesting, were left entirely to the growers concerned. It was thus hoped to get a fair estimate of the usefulness, when grown under normal management, of the varieties both to growers and from Institute of Brewing trials on these crops, to brewers. However, owing to the small size of the plots and the fact that they were sometimes established in gardens made more or less derelict by wilt, some economies in management had to be expected. In fact, each plot formed an unconnected and uneconomic unit for harvesting and drying, to be fitted into the farm's normal programme with a minimum of disturbance. For these reasons both quality and quantity of crop may sometimes have suffered, so that the yields and brewing trial results probably do less than justice to the real potentialities of these varieties.

The new wilt-tolerant varieties

Density (D1) is a late-season hop of vigorous growth-habit and high yield, somewhat resembling OR55 in appearance ; it has a relatively high resin content. The cones are small and compact and the ratio of hops to leaf and bine tends to be low. Thus while the structure of the cone may help machine harvesting the leafiness may offset this advantage. The variety is very susceptible to downy mildew, and a thorough programme of control is necessary from the outset if infection of the rootstocks (with consequent shortening of the life of the plant) is to be avoided. Planting distance, type of training and other cultural practices such as ' pulling ' should take into account the vigour of the variety and the fertility of the land, with a view to avoiding dense ' heads ' and ' housing-in '. If by such measures downy mildew can be kept under control the crop may be allowed to hang to full maturity and weight. On a deep, well drained, brick-earth alluvium a trial plot had a maximum yield calculated at 33 cwt per acre. The variety has proved acceptable in a high proportion of copper-hopping trials at 25 and 50 per cent replacement of the control grist according to α-soft resin content, but a higher rate of substitution is less acceptable.

Defender (D3) is an early-season hop of vigorous growth habit and good yield. The cones, which are of a characteristically flat appearance, are small to medium in size and loose in texture, but in some seasons are comparable to Fuggle in size. The ratio of hops to leaf and bine is average. The variety is very susceptible to downy mildew, but because of the early maturing date, the general considerations governing the control of this disease in Density apply to a lesser degree. In particular, since it is sparing in the production of bine, little control of growth habit is possible by ' pulling '. On fairly typical heavy Fuggle land a trial plot had a maximum yield calculated at 26 cwt. per acre. The variety has proved acceptable in a high proportion of copper-hopping trials at 25 per cent replacement according to α-soft resin content, but at 50 and 100 per cent replacement it is less acceptable.

Janus is a mid-season hop of moderate vigour and yield. The cones are characteristically bold and loose-textured and resemble those of Fuggle. The ratio of hops to leaf and bine is high and the

* A full botanical and technical description of these hops appears elsewhere in this Report (p. 110).

general bearing habit of a type which may suit machine harvesting. Susceptibility to downy mildew is average so that control of this disease should be no more difficult than in Fuggle. Planting distance, ' pulling ' and other cultural practices should take into account the moderate vigour of the variety and the fertility of the land if maximum yields are to be obtained. This hop appears to be very sensitive to adverse soil conditions. It is likely that on most soils yields could be increased by close planting. On a silty loam of good texture and satisfactory drainage, but slightly deficient in potash, a trial plot had a maximum yield calculated at 19 cwt. per acre. The variety has proved acceptable in a good proportion of copper-hopping trials at 25 and 100 per cent replacement according to α-soft resin content, but at 50 per cent replacement it has been somewhat less acceptable. It is of interest that because of close similarity in the proportion of soft resin content to Fuggle, replacement on a weight-for-weight basis is possible.

All three varieties are sufficiently wilt-tolerant to provide control of the disease in the field.

The future of wilt-tolerant varieties

The brewing industry as a whole has laid down no standards by which similarities to, or differences from, the more popular characteristics of the Fuggle can be assessed in new varieties. It follows that attempts to produce a wilt-tolerant Fuggle must remain largely ' hit-and-miss ', so that it seems unlikely that any of these three varieties will find general acceptance as a substitute for Fuggle. Present evidence suggests that such a variety will not only have to be very similar to Fuggle but will also have to possess some extra advantage to encourage brewers to take it up. The most obvious such advantage would be a cropping capacity allowing of marketing at very favourable prices.

If a satisfactory wilt-tolerant substitute for Fuggle is not produced, the difficulty of growers on ' wilt-farms ' in meeting brewers' requirements may increase the movement of basic quota away from the wilt areas. Meanwhile varieties are offered which have done reasonbly well in brewing trials. Their reception by brewers in general will at least provide a measure of the standards at present available for guidance in their selection.

Summary

A description is given of three new wilt-tolerant hops, *Density*, *Defender* and *Janus*, which have recently been released.

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RUSSETING AND CRACKING OF COX'S ORANGE PIPPIN APPLES

By H. B. S. MONTGOMERY

The problem of russeting and cracking of Cox's Orange Pippin apples is by no means a new one but during the past season it has been more serious than for many years and it is opportune to consider what is known about it, ignoring for the moment forms of cracking of the fruit due to virus diseases.

Cox's Orange Pippin is usually described as bearing a fine russet around the eye, on the cheek, and in the stalk cavity. This natural tendency to russet has been reduced to some extent in recent years by the use of certain fungicides, especially captan, that appear to favour the development of a smooth glossy finish to the fruit. On the other hand completely unsprayed trees often bear heavily russeted and cracked fruit.

The skin of the flower before blossom persists round the developing fruitlet and finally develops into the skin of the mature fruit. It is, therefore, vulnerable to injury over a long time and even very small injuries in the pre-blossom period can show as serious blemishes by picking time. Thus the injury caused by a copper-containing spray applied pre-blossom may show as tiny purplish spots on the fruitlet soon after petal fall and later appear as a disfiguring cracked russet. Traces of iron in the water used for spraying have been suspected of causing injury in Denmark. Frost damage may split the skin to leave scars on the full grown apple or lift the skin with later development of green blotches, corky patches or russety rings. Desiccating winds may possibly also cause russeting. Where russet originates early in the season the fruits may also be stunted or distorted in shape.

Russeting has also been found to be associated with poor foliage and may then originate after blossom, possibly as a result of excessive exposure of the fruit to weather conditions. Various factors may contribute to a reduced leaf area on a tree but nutrient deficiencies, fungal and virus diseases, and spray damage are among the more important ones.

Deficiencies, especially of potash and magnesium, obviously directly reduce foliage, as does the application of phytotoxic sprays. When captan was first used the improved skin quality of the fruit was remarkable but where it has been used for several years without the support of fungicides that control mildew, many of the apples are found to be heavily russeted. In these cases the unchecked spread of mildew has resulted in the loss and crippling of many of the leaves, thus indirectly causing the poor skin of the apples ; the data supporting this view will shortly be published by Dr. M. H. Moore and Miss Margery Bennett. Fruits on M.IX are slightly more prone to russet, possibly because they are less well protected by leaves on this rootstock.

These forms of overall russet can be a serious cause of down-grading fruit but often it is possible to locate the cause of the trouble and to do something to reduce it in subsequent years. In 1958, however, the cracking was commonly found around the stalk end, usually on patches of scaly cork, and often on apples that were otherwise excellent. Sometimes the full extent of the injuries was not realized until the fruits were picked. This type of injury has been found in other seasons, also, although to a less extent ; it was well illustrated in the Annual Report for 1928, '29 and '30 Supplement (1931), opposite page 155. It is more difficult to identify the possible causes of this cracking and to suggest methods of avoiding them.

The fact that it was so widespread in 1958 and that it was not linked with any particular spray material, suggests that we must look for some weather condition to account for it. Cracked fruits have been carefully examined to decide if frost could account for the injury, but this is held to be unlikely. In addition, it has been found in places where no damaging temperatures were recorded. In view of the exceptionally heavy rainfall during June and August it is tempting to blame the persistent wet weather. Some support for this view has recently appeared in Denmark where it has been shown that trees protected from rainfall by polythene bore unrusseted fruit, whereas the fruit on trees exposed to rain were russeted and cracked. A correlation was also shown between the amount of russet and the rainfall for different years. It is possible that the water lodges in the stalk cavity and dries out only slowly, especially where two apples are on the same spur. The injury may begin in a manner similar to the production of ' Cox spot ', which is due, it has been suggested, to the leaching of nutrients from the leaf. Alternatively uptake of water through the skin may rupture the cells. In addition, moisture fluctuations may cause the cracking of skin already finely russeted, or in combination with temperature changes lead to uneven cell division or enlargement, with consequent stresses that might lead to cracking.

If the cracking is due to the wet weather, why should some orchards be less affected? Impressions formed over several years when selecting apples for storage experiments from the Cox's Orange Pippin manurial trial at East Malling suggested that cracking was worse on the clean cultivated plots, especially where nitrogen and potash were applied and that it was very much less where the trees were in grass or were receiving phosphate only. Detailed grading of the fruit from this trial carried out by the Fruit Nutrition Section in 1956 and 1957 gave some support to these impressions, especially in 1957 when the fullest records were taken. In that year the results, as yet unpublished, showed that there was less cracking in grass than in arable, and more where potash was applied than where it was omitted.

In conclusion it is likely that severe cracking such as was experienced in 1958 was due to unusual climatic conditions and that it may not recur so severely again for many years unless these conditions are repeated. A similar wet June and August was last recorded ten years ago, in 1948. Nevertheless these blemishes affect a proportion of the crop in many years and everything possible should be done to reduce their incidence; such measures include the avoidance of damaging spray materials, the maintenance of a good foliage, grassing down where conditions are suitable for this form of management and ensuring so far as possible that the nutrition of the tree is well balanced, in particular that the potash status is not excessive.

Acknowledgements

It would have been impossible to have written this note without the ready co-operation of many colleagues at the Research Station, both in making available conclusions from unpublished data and in discussing the ideas put forward here. This help is most gratefully acknowledged.

Summary

Some of the causes of russeting and cracking, especially stalk-end cracking, of Cox's Orange Pippin apples are discussed, and practical suggestions made for reducing losses from these blemishes in future years.

PROGRESS IN RESEARCH ON *VERTICILLIUM* WILT AND VIRUS DISEASES OF HOPS IN 1958

By R. V. HARRIS

This is a review of items of special interest to hop growers in the general research report of the Plant Pathology Section for 1958 (p. 25).

Progressive *Verticillium* wilt

Research on tolerant varieties

Three new tolerant varieties released in 1956 and 1957 have now been named and fully described

Readers should turn to page 161 for an account of Density, Defender, and Janus specially written for hop growers who are thinking of trying out one or all of them.

At present there is virtually a choice of only two wilt-tolerant varieties which growers can plant on their infected land with confidence of their continued acceptance by the brewers, i.e. Whitbread's Golding Variety and Bramling Cross, and there now seems some doubt on the future of the latter.

The Research Station released these three new hops as an emergency effort to meet this acute shortage and not because their acceptability to the growers and brewers as a whole was by any means finally sure. Such a prediction would have been foolhardy indeed on only ten years of intensive and comparatively restricted tolerance, growing, and brewing trials. All that could be claimed was that in these trials all three had maintained adequate wilt-tolerance, that each had shown indications of having some additional cultural advantages such as early season or resistance to downy mildew, and that some large breweries which had samples under the trials of the Institute of Brewing had not rejected them but on the contrary had reported their readiness to substitute them in some proportion for their standard Fuggle growth in the copper. It is at least probable, therefore, that one or more of the three will serve as stop-gaps until a range of tolerant Fuggle substitutes appears. Their future, when they become available from 1960, now therefore rests with the industry as a whole, and growers who are looking for a new tolerant variety to plant their wilt-land are at least advised to try them.

Meanwhile, the Wye-East Malling joint breeding project has made good progress this year and now approaches the stage for the advanced farm trials of a short list of hopefuls.

Tolerant varieties on some farms are wilting severely

We have been studying for some years a single farm in the Weald where the occurrence of wilt in tolerant varieties has been unusually and increasingly severe, and last year another such farm was found.

This year by means of a survey of farms growing the tolerant varieties in this area, made possible by the invaluable co-operation of the Association of Growers of the New Varieties of Hops, eight other similar cases were discovered, making ten in all. This is, of course, disturbing as many growers depend on the tolerant varieties to maintain their quota. Much of our research power is being concentrated on discovering the why and wherefore of these exceptional outbreaks, none of which is exactly like the usual progressive outbreak in Fuggle although they are comparable with severe fluctuating outbreaks on that variety.

Two possible explanations at once occur. First, that a more virulent strain of the progressive fungus has appeared and is spreading. Or second, that certain conditions peculiar to these particular farms have enabled the progressive fungus to build up in the soil, once the Fuggle or other sensitive hops had been grubbed, to a level sufficient to overcome in some degree the resistance mechanisms of the tolerant varieties we described last year.

The first possibility, if true, would be serious and might call for direct eradicant action by the authorities similar to that at present used against progressive wilt in the sensitive varieties. But so far our experiments have given no conclusive proof that this is so. It would, however, be foolish to regard this negative as final and further research on the variability of the progressive fungus is in progress, including special studies at Rothamsted to see whether such changes are a chance affair and thus unpredictable, or whether definite races and their crossings are involved.

Regarding the second 'environmental' possibility, there is so far no evidence for this either, but field experiments in certain of these gardens are being laid down this winter (1958-59) to test this in further detail.

Do tolerant varieties reduce the Verticillium in the soil?

The ten outbreaks in tolerant varieties mentioned above are regarded as special cases. Generally speaking, the planting of tolerant varieties following wilted sensitive ones might be expected to reduce the infective power of the soil, and the large-scale ' outside ' trial in a commercial garden to test this, which we reported last year, is now well established.

Research aiming at control by elimination of the progressive wilt fungus

Speeding up the diagnosis of new wilt outbreaks

As the *Verticillium* fungi causing progressive and fluctuating wilt cannot be told apart in glass-tube culture, progressive wilt can be diagnosed only by test inoculations into hop plants compared with the inoculation of identical plants with cultures from known progressive and fluctuating sources. This is a lengthy and cumbrous business allowing a new outbreak to get well under way before it can be labelled. However, we saw in last year's review that hop roots can be infected by the minute thin-walled spores called *conidia* as well as by fungal threads (hyphae). Attempts were begun this year to find a more rapid method of distinguishing the two fungi by following with a microscope the invasion of detached roots placed in a jelly containing conidia from the sources to be compared. Unfortunately, however, this method did not work because of contamination by other fungi and by bacteria ; we are now trying it again but using complete root systems growing in soil in pots.

Do susceptible weeds tolerate invasion by the progressive fungus as do tolerant hops, and are the highly resistant cereals and grasses actually immune to infection?

Last year we reported on research leading to the discovery of the definite ways by which the sensitive and tolerant hop varieties check invasion by the fluctuating and progressive fungi respectively. Similar examinations of weeds, cereals, and grasses, begun this year, have shown so far that the common weed hosts like the hops differ among themselves considerably in their capacity to resist invasion by the progressive fungus, but that all can become infected in some degree ; also that none of the cereals and grasses tried are totally immune. All these hosts appear to have defences resembling those in hops. It is thus obvious that these alternative hosts of *Verticillium* must differ among themselves in their influence on the survival of *Verticillium* in the soil both under hops and in fallow, and these differences must be taken into account in any programme aiming at speeding up the extermination of the fungus from infected soils.

The severity of a progressive wilt attack depends partly on the number of conidia available in the soil

The progressive fungus persists in the soil mainly in decaying infected plant material such as dead hop bines and ploughed-in weeds, its conidia travel through the soil, and it is these spores which infect healthy hop roots. This means that as the strength of an invading army can to some extent be measured in terms of the number of men composing it, so the strength of the invading fungus can be estimated in terms of the number of conidia in the soil around the roots to be invaded. The rate at which a hop plant is killed by the disease should therefore depend not only on its internal resistance or tolerance, but on the number of conidia which arrive at the outer root surfaces.

In an experiment made this year to test this conclusion, suspensions in water of conidia from the progressive and from the fluctuating fungus were made at various strengths, i.e. with varying numbers of conidia per unit of volume. The wilting powers of these suspensions were then compared by watering different volumes of them and therefore different numbers of the conidia into soil in which healthy Fuggle N plants were growing. When the progressive fungus was used, the rate of wilting increased according to the number of spores applied, but with the fluctuating fungus only a slight difference in wilting occurred with the ' stronger ' concentrations of spores. With the fluctuating fungus the internal resistance of the sensitive Fuggle N thus held its own, whatever the size of the invading army of spores. With the progressive fungus this resistance was soon overcome when the invading army was strengthened.

The important rôle of dead infected plant material in the survival of the fungus in the soil

If, as previous research has suggested, infected decaying plant debris is the principle survival—base of the fungus in the soil, and if the infection of a healthy hop root is begun by the fungus conidia, then such dead infected material should produce abundant infecting conidia in the soil.

This was strikingly proved by an experiment in which one or more fragments of dead, infected bines were buried in soil in small pots from which the drainage water was led to other pots containing healthy Fuggle plants. It was found that the use of a single fragment of bine infected with the progressive fungus, brought about the wilting of about half of the Fuggle plants in the corresponding pot ; three fragments wilted the lot. On the other hand three fragments infected with the fluctuating fungus caused infection of all the Fuggle plants but produced no wilt symptoms at all. These results

demonstrate, among other things, the great importance of cutting out and burning all bines as soon as they show wilt symptoms, even in a garden of a tolerant variety. For as soon as they die and return to the soil they become sources of profuse crops of infecting conidia.

Speeding the ' cleaning up ' of wilt-infected soil

It seems likely from the work described above that the prospects of freeing soil from the progressive fungus, or at least reducing its concentration to a very low level, in a reasonably short time, are quite hopeful. Liquidate its principal bases or hide-outs in the soil by grubbing infected hops and other hosts, by keeping weed hosts from re-establishing themselves, and possibly by occupying the soil with the roots of a highly resistant or near-immune crop such as a cereal or grass, and the soil population of *Verticillium* should quickly decrease and possibly die right out, for the decay of the original infected plant debris is naturally automatic though it can also be speeded up by various cultural treatments.

Three field experiments, two at East Malling and one on an outside farm, designed to test such soil amendments and arrive at a practical programme of extermination, were reviewed last year and their first year's results, which became available this year, are distinctly promising.

Virus diseases

No final conclusions have yet been reached on how nettlehead, split leaf blotch, and mosaic spread into and within hop gardens

If a crop virus disease is found not to be spread by one of the many insects or other animals normally inhabiting the crop in question, looking for the agent of spread, the vector, is like searching for a needle in a haystack. And yet, knowledge of the agent, or agents, of spread is an essential preliminary to devising an adequate control.

In spite of the persistent lack of conclusive clues for any of these three principal diseases, nevertheless over the past years our research has made available a wealth of information on their mode of spread and behaviour in hop gardens, and from this we are able to narrow down the answer to the nettlehead vector problem to two most probable alternatives, (1) that the virus is mainly located in plants other than the hop, such as clover and weeds, whence it is carried to hops only occasionally by insects not normally feeding on that crop, but alighting on it by chance, or (2) that it is spread through the soil by some agency as yet unknown. A summary of ten years' research on nettlehead and split leaf blotch, and the tentative practical conclusions to be drawn from it, has been specially prepared for growers and appears on page 157.

Finally, regarding the search for the natural vectors of mosaic, we have to report that the tests of certain species of mites noted in last year's review have so far provided no positive clue.

Summary

Items of special interest to hop growers in the Station's Report of research in 1958 on *Verticillium* wilt and the virus diseases of that crop are reviewed and discussed.

PROGRESS IN RESEARCH IN FRUIT CROPS IN 1958

By H. B. S. MONTGOMERY

It is essential to read Part II of this report to keep informed of the progress of all the many lines of research under investigation. Fruit growers, however, often have difficulty in finding the items of practical interest to them amongst the more scientific matters reported and this article may help them by drawing attention to many of the more practical items, especially if full use is made of the page references given.

Rootstocks

The semi-dwarfing apple rootstock M.26, which was described in last year's Annual Report pp. 48-9, was not released to Members in autumn 1958 pending study of the cause of some varieties, notably Lord Lambourne and Fortune, budded on this stock being slow and irregular in breaking into growth in the spring. Cox's Orange, Worcester, and Laxton's Superb made good maiden growth ; most of the slow-starting trees of Lambourne and Fortune caught up with the others by the end of the season. The established trees on M.26 continue to justify fully the good report made on them last year.

The search for reliable rootstocks for pears continues (p. 7). Two field trials of clonal free pear rootstocks were grubbed in 1958 because the fruits of Conference and Williams' Bon Chrétien on many of the rootstocks were small and gritty, but four selections are considered worth using in further trials. Most free pear rootstocks are very difficult to propagate vegetatively and there is, therefore, special interest in the Chinese pear *Pyrus calleryana*, which can be readily propagated by cuttings and is said to be very satisfactory in Australia. Trees of Conference on this rootstock, now in their fourth year, have made less growth and cropped more heavily than on Quince A. The incompatibility of Williams' Bon Chrétien on Quince has always been very variable, some trees breaking off at an early age whereas others have a strong union throughout their life. The reasons for this are being investigated by testing on Quince B the compatibility of buds from trees of different degrees of compatibility, and also by using one source of Williams' Bon Chrétien on clones of Quince A derived from five selected single layers. These 4-year-old trees on Quince A are now showing marked growth differences. Attempts are being continued to produce pear/quince hybrids for rootstocks and some 40 fruits were obtained from crossing Beurré Superfin pear and Quince A (p. 9). Last year's fruits from this cross were seedless.

Propagation

Work on softwood cuttings under intermittent mist spray has continued (p. 8). Two apple and two plum rootstocks have been used in a range of treatments including amongst others growth substance treatment, bottom heat, and transference from the mist in autumn or the following spring. The mist frames have been enclosed with a polythene roof and glass slides.

With hardwood cuttings (pp. 8 and 17) the most critical stage is their transference from the winter storage bins to the nursery bed. Thus in 1958 spring, many well-rooted cuttings of Myrobalan B were too forward when planted out and they suffered severe scorching of their leaves. A wide range of other rootstocks, namely Brompton, St. Julien A, Pershore, Crab C, M.II, M.VII, and MM.104 showed no injury. Where the best treatments were used at least 50 per cent of the cuttings of all these rootstocks, including Myrobalan B, rooted and grew well, and this is considered to be commercially satisfactory.

Experiments with cuttings of different lengths showed that both shorter and longer than normal 12 in. cuttings rooted satisfactorily. With the shorter cuttings the buds could be put into the young growth, whereas with the longer cuttings it might be possible to save a year in the nursery by budding directly into the cutting during the summer after it has been taken from store.

Pruning

In a pruning trial with pears and another with plums (p. 8), the unpruned trees are bearing more fruit than pruned trees in the early years, even Comice bearing a few fruits at two-years-old. But summer-pruned pyramid plums suffered less branch breakage than unpruned trees or winter-pruned standard trees.

Fruiting

One of the possibilities being investigated in connexion with the poor setting of Cox's Orange Pippin is the degree of fertilization of the flower required for the development of a fruit (p. 9). Some other varieties tend to overcrop and become biennial ; work with copper sulphate sprays to defoliate in early summer, and thus reduce the formation of fruit-buds for the next season, showed that after this treatment the trees carried two good crops in succession before reverting to biennial bearing (p. 9).

The effects of defoliation treatments, applied by hand, on the pattern of development of the buds is being studied by dissecting buds under the microscope. Interesting differences after treatment in 1954 and 1956 were observed and they are the subject of further experiments to determine why they should occur. For thinning blossoms naphthalene acetamide has given encouraging results.

Strawberries

The new clone of Royal Sovereign M.415 again yielded more heavily than M.48. Heat-treated clones of a number of other varieties grew more vigorously than untreated clones, but crop differences were smaller than in previous years, possibly on account of virus spread within the trial. Another unexpected result was the failure of a number of varieties including Merton Princess, Royal Sovereign, and Talisman to respond to deblossoming in 1957 by producing an increased yield in 1958 (p. 10).

Loganberries

Frost at bud-break in March damaged many of the fruiting laterals in the new Loganberry trials but a fair crop was carried on the secondary laterals that developed in their place (p. 10). The most promising of the five virus-tested selections produced an average yield of 9 lb. per plant ; this is equivalent to about 3 tons per acre. The berries on the secondary laterals were of good size but as they ripened later they caused a prolonged picking season. The virus tested sub-clone L478 from the original East Malling selection, which has been propagated in collaboration with Long Ashton Research Station, is becoming available through the Nuclear Stock Association but many of the bedded plants and rooted tips available in 1959 are likely to be required for further propagation.

Currants and gooseberries

Hybrids between currants and gooseberries are being developed as a beginning in the quest for larger currants and spineless gooseberries ; a number of these seedling hybrids have already been planted out (p. 10). Various tetraploids and selfed varieties are being produced with a view to simplifying the task of making some of the crosses that may be required later on in the programme.

Weedkillers

Weeds in Royal Sovereign strawberry plots were again safely controlled by 3 lb. per acre of 2, 4-DES applied monthly during the summer, with 2 lb. per acre of dinoseb in the autumn. MCPB caused no damage to Mendip Cross black currants at up to 10 lb. per acre in August 1957, but on raspberries some damage resulted. The treatments are being continued and in addition the persistent weedkillers simazin and monuron are being tried on a range of top and soft fruit (pp. 9 and 11). Dalapon in November, at up to 10 lb. per acre, did not damage Malling Exploit raspberries but failed to give good control of couchgrass.

Interpretation of results

Many hours of arithmetic are involved in the examination of the data from even quite a simple experiment, although full use is made of electrically-driven calculating machines. This fact not only delays the interpretation of trial results but also in some cases rules out the most suitable methods of analysing the data because they take too long. Arrangements have now been made for the electronic computor at Rothamsted to be used for some of our data, with the result that the accumulation of over a hundred analyses that remained at the end of last year has now been cleared (p. 13). The electronic computor will also enable us to study the connexions between the many different records and to relate them to various factors that might be affecting the results, a process known as multivariate analysis.

Growth studies

Interesting differences are developing in an experiment on the effects of pruning and de-blossoming young apple trees on growth, as measured by the trunk girth, and cropping (p. 15). Five years after

planting, the very lightly pruned trees of all four varieties on M.XVI have shown a 9 per cent increase in growth over the heavily pruned, but little effect of de-blossoming, whereas on M.IX de-blossoming has produced an 18 per cent increase in growth, and pruning very little. Although the Cox's Orange Pippin trees have carried more crop than the trees of Laxton's Superb, the difference in growth between fruiting and de-blossomed trees was much greater with Laxton's

The effect of shading on growth is being studied on rooted layers in pots (p. 15). As might be expected the biggest increase in weight was made by the plants in full daylight but the largest leaves, greatest leaf area, and the longest shoots were produced in light shade (70 per cent daylight).

Some of the difficulties in growing apple trees in culture solutions appear to have been overcome ; in fact, some of the trees growing in solutions gained more weight than those in John Innes compost (p. 16). The method uses 13-in. pots, fitted with special polythene liners to hold the solution. They are sunk in the ground and a continous stream of air bubbled through the solution.

A possible method of ensuring wide-angled crotches on young plum trees has emerged from fundamental studies on the influence of leaves on the growth of shoot tips (p. 15). In an experiment on rapidly growing stems produced by cutting maidens hard back, the removal of 6 or 12 leaves from the terminal cluster of unexpanded leaves when the shoot had reached the desired height resulted in wide angled shoots growing out. The length of these shoots was improved by subsequently cutting out the leader above the defoliated region. Unfortunately when this method was tried on normal nursery trees of apple, plum, cherry, and pear very poor results were obtained, possibly because the shoots were not growing strongly enough when they were treated.

Carbohydrate resources

Results of the first season's study of the changes in the concentration of carbohydrates (sugars, starch, etc.) in the wood and bark suggest that in spring, carbohydrates are used up rapidly during the first flush of growth and then rapidly replenished, possibly by the activity of the expanded leaves (p. 16). This is followed by a further period of rapid use during shoot growth in early summer and when this growth ceases stores accumulate again. All parts of the tree appear to be equally important in storing the surplus, and all give back about the same proportion of what is stored.

Spray damage

Field trials to study damage have now been running for a number of years and valuable information is being accumulated on the effect of seasonal conditions on the injury caused by commercial spray materials. Relatively little damage resulted this season (p. 37).

Research on the physiology of spray damage has largely concentrated on the uptake of copper by the leaves and what happens to this copper in the plant. An interesting development from this work has been a similar study of the uptake of magnesium, and it has been found that Epsom salt is not the most efficient chemical for getting magnesium into leaves, although at present it is the easiest to obtain. Under most conditions other magnesium salts, such as the chloride and the nitrate, appear to be taken in more readily (p. 37).

In addition to further work using copper sulphate, important work has been begun on the effect on the growth of fruits and tree of the removal of the spur leaves that are so often more or less damaged by pre-blossom lime-sulphur (p. 18).

Nutrition

As the soil in the long term manurial trial on Plot C2 has been becoming rather acid where sulphate of ammonia has been applied each year since the trial began in 1931, the nitrogen treatment was changed this year to ' Nitro-chalk ' (8 cwt per acre), applied half in February and half in April. This should avoid any further acidification of the soil. Although all the trees in this experiment blossomed well, the only trees to set well were those grassed down in 1953 (p. 20). The other trees carried most of their crops on the north-east side and at picking time these parts of the trees were partly defoliated. The heavier cropping trees did not show this premature leaf drop. Soil analyses by the NAAS at Wye show that the soil that has received no nitrogen for 27 years is not unduly low in total nitrogen content. The experimental trees on these plots do not show obvious signs of nitrogen shortage where the soil is cultivated, nor do their leaves have a consistently lower content of nitrogen than leaves from trees receiving nitrogen applications. Although it is possible that some harmful effect of the acidification of the soil by sulphate of ammonia may be masking the true position, it does seem likely that the cultivated soil in this trial is still able to supply most of the nitrogen required by these Cox's Orange Pippin trees on the very vigorous rootstock M.XII. Obviously there is an urgent need for more knowledge to guide us in the proper use of nitrogenous fertilizers.

In a small experiment on M.II rootstocks growing in grass and in cultivation with an adequate supply of moisture supplied by irrigation, the extension growth in grass with the high rate of nitrogen was as good as the best growth under clean cultivation (p. 21).

As might be expected in the past very wet season, direct effects of irrigation have been very small but the crop yields have been related to plant size and in general the larger plants are those that were watered in previous seasons. This was true with Laxton's Superb apple, Malling Jewel and Malling Exploit raspberries, and the black currant Amos Black (p. 21).

A feature of the soil management trial on Laxton's Superb has been the deteriorating condition of the trees in clean cultivation and the much improved state of the trees in grass where sulphate of ammonia is applied annually at 6 cwt per acre (p. 21).

Mineral composition of apple plants

Some interesting effects of soil moisture on the composition of plants grown for 13 weeks in pots have been found (p. 23). Plants in moist soil contained about 30 per cent *less* nitrogen, 50 per cent *more* phosphorus, and 15 per cent *more* potassium per unit of dry matter than plants in the drier soil, although as the plants made more growth in the moist soil, the *total* amounts of all these elements was also the greater. No explanations are yet being advanced for these observations.

Bacterial diseases

Further research on the antibiotic streptomycin has shown that although it is absorbed by cherry leaves and moves through the leaf-stalks, the rate is too slow for the antibiotic to be generally distributed through the whole plant (p. 25). It is probable that enough goes directly into the green tissues of the spurs to assist in controlling bacterial canker. In spite of this, however, early autumn sprays of Bordeaux mixture or of colloidal copper on cherry trees gave better results than streptomycin. Almost complete control was achieved by Bordeaux mixture applied in mid-August, mid-September, and mid-October ; cotton seed oil prevented the early defoliation often caused by Bordeaux mixture but did not affect the disease.

Fire-blight disease of pears is now in this country and a full description of the disease and the measures being taken in an attempt to eradicate it appears on p. 151.

Fungal diseases

The leaves of certain close relatives of the apple (*Malus* spp.) that are scab-resistant have been examined by the Biochemistry Section to see if they contain any special chemical compounds that might be concerned with their powers of resisting the scab fungus (pp. 19 and 25). Certain marked differences in composition have been found and are being further studied with a view to transferring these characters to cultivated apple by plant breeding.

Cinnamic and *o*-coumaric acids, two chemicals related to the natural chemicals that resist scab in the apple, gave good control of this disease in greenhouse tests. In the field they were tested on rows of heavily infected rootstocks and here also they were found to inhibit scab (p. 29). Further development of this type of systemic fungicide is necessary before an efficiency comparable with that of concentrated lime-sulphur could be achieved.

Further work on the application of concentrate sprays, in collaboration with the National Institute of Agricultural Engineering, showed that variations in the size of the spray droplet and in the volume of lime-sulphur spray, without altering the actual quantity of lime-sulphur applied per acre, produced no marked effects on the control of apple scab and mildew (p. 28).

Considerable attention has been given to the possibilities of curative sprays for scab (p. 29). Records of spore dispersal and meteorological conditions in relation to infections were taken as part of a country-wide survey. The recorded ' Mills periods ' were used to time the application of curative sprays for comparison with normal protective sprays on a plantation of Cox's Orange Pippin. In the greenhouse, potted rootstocks were used to study the relationship between the duration of leaf wetness and the severity of infection by scab, and special attention was paid to the effects of breaking the periods of leaf-wetness. This greenhouse method was used also to compare the protective and eradicant properties of lime-sulphur, organic mercury compounds, and other spray chemicals.

The relatively cool summer weather assisted the greenhouse tests of chemicals against powdery mildews (p. 36). In the past, sunny periods have so raised the temperature in the greenhouse that the amount of mildew infection has been reduced and difficulty has been experienced in getting enough spores produced. The season for testing was also lengthened by using barley seedlings as test plants, when apple seedlings were not available. Most of the chemicals tested were related to DNOPC (Karathane), but under the greenhouse conditions none of them proved superior to DNOPC. It was shown, however,

that the simpler chemical DNOP was quite as toxic to mildew and no more likely to cause plant damage.

A bud burst spray of DNC petroleum has been shown, in a field trial on apple rootstocks (p. 00), to have a considerable effect in reducing the number of buds that appear in the spring with overwintered mildew, and it may prove a useful supplement to the winter cutting-out of infections, and to summer sprays against mildew.

Against *Gloeosporium* storage rots, cinnamic acid as a spray in September or a dip after picking gave some control, but a spray of captan in September was more effective (p. 29).

Virus diseases

Star-crack disease of apples is widespread and affects many varieties ; it has now been proved to be due to a virus. Tests with buds from apparently healthy trees of Lord Lambourne have shown that they were carrying the virus that causes stem pitting of Virginia Crab rootstocks in U.S.A. The identification of these ' new ' viruses (p. 27) means that the health standards of the Mother Tree Scheme may now be further improved.

The strain of Williams' Bon Chrétien that is compatible with Quince A rootstock has been successfully heat-treated to free it from vein yellows infection. Various clones of Packhams' Triumph have been imported from South Africa but they have all proved to be virus-infected ; the best clone will now be heat-treated. With plums, the rootstocks Common Plum and Marianna, and the varieties Victoria, Ontario, and Ruth Gestetter are now apparently virus-free after heat treatment.

Virus-infected trees of Early Rivers, Napoleon, and Merton Bigarreau cherry, planted in 1953, have yielded less fruit than virus-free trees, although they were showing no clear symptoms of disease (p. 27). In the case of Early Rivers, the healthy trees cropped three times as heavily as infected trees.

Earlier work on green petal disease of strawberries showed that certain leafhoppers, especially *Euscelis* species, could transmit the virus in clover but they were unable to infect strawberries. It has now been proved that another leafhopper, *Aphrodes bicinctus*, can infect strawberry plants and it has been found breeding on strawberry plants in the field (p. 28). Some of the troubles in so-called tolerant varieties of strawberry are due to soil-borne viruses and one of these, raspberry yellow dwarf virus, has been shown to be responsible for strawberry mosaic disease in Cheddar and in Kent.

Pests

The most important development in relation to the fruit tree red spider mite has been the discovery of mites resistant to the acaricide chlorbenside. The evidence for this was obtained in a trial on Worcester apples at the Essex Institute of Agriculture at Writtle, the details of which are reported on p. 131. The new organophosphorus acaricide, amiton, gave excellent control in the same trial (pp. 31 and 35). There is a real risk, however, of the mites developing resistance to other acaricides and it is, therefore, of interest to see how far predators may help in controlling the mite. In the field trial of the combined effect of certain insecticides and fungicides that has now been running for six years, predators were still sufficiently abundant in 1958 to control the mite, in spite of the fact that the numbers of both mites and predators were very low in 1957 (p. 31). Insectary experiments with *Typhlodromus* mites which prey on the fruit tree red spider mite are being continued.

In search for a better control of the apple-grass aphid by pre-blossom sprays, two systemic organophosphorus compounds and a new carbamate were compared with a standard BHC-DDT mixture (pp. 31 and 35). They were all effective against the aphid but the control of apple sucker was variable. An interesting point revealed by chemical analysis was that insecticides applied to several varieties on the same date differed in their deposits by as much as four to one, owing to the different stage of development of the buds of each. The significance of the result obviously depends on the habits of the insects concerned but such different deposits might be a factor in some of the cases where, in a mixed orchard that is uniformly sprayed, control of a pest may be achieved on one variety but not on another.

Both ryania and diazinon gave better control of codling than did lead arsenate in 1956 and 1957 but like DDT they encouraged the build-up of the fruit tree red spider mite. In 1958 another organophosphorus compound and the new carbamate referred to above were tested in a field trial (p. 31). Determinations of lead arsenate and other residues at harvest time are being made in parallel with these trials (p. 35).

Further work on the *Bryobia* mites has shown that the species on apple and pear are probably identical, and distinct from the species found on gooseberry. The strain on apples in Kent is parthenogenetic and no males have yet been found (p. 32).

The strawberry seed beetle has caused much damage in some localities and it has proved difficult

to control. A close study of its life history and habits has revealed that the younger larvae prefer weedy conditions to clean cultivated ground, and that the beetles that damage the crop probably come into the beds from the headlands and adjoining ground (p. 33). Laboratory and field tests of aldrin, dieldrin, and endrin have shown that endrin is relatively ineffective against the beetle and that aldrin is superior to dieldrin. An application of aldrin to the soil before blossom left no residues on the fruit, but sufficient aldrin remained in the soil to kill the beetles throughout the fruiting period.

Research on the part played by migratory nematodes in the poor growth of apples on old apple soils is now directed mainly to discovering what effect nematodes can produce on apple trees in the absence of other complications, such as those revealed in the soil warming experiments reported last year. This approach involved developing cultures of the nematode *Pratylenchus penetrans*, free from other species, bacteria, and fungi, and of finding methods of inoculating apple tree roots with them. So far the rate of multiplication on potted seedlings has been too slow, and even on the most promising host, a Canadian vetch, the rate is not really fast enough (p. 33). These methods are now to be compared with a small-scale culture method which was used in the past and gave better results. Examinations of field problems have included a case where strawberries failing and dying in patches in a light sandy soil were found to be heavily attacked by *P. penetrans*, and a case of black currants with a heavy infestation of two species of *Rotylenchus* and poor growth of fine roots. In both cases further experiments are required to establish that the nematodes were in fact responsible for the poor condition of the plants.

Work is going ahead on many other insects, including leafhoppers, raspberry aphid, black currant gall mite, and woolly aphid (pp. 31 and 32).

Fruit storage

After several years' experiments with the Cox's Orange Pippin apples from the long-term manurial trial, it is now possible to forecast very accurately how the fruit from each manurial treatment will keep, as regards both *Gloeosporium* rots and breakdown (p. 39). So far it has not been possible to determine what has happened to the fruit to render it of good or of bad keeping quality. Amongst the characters being studied are respiration, chemical composition, cell walls, cell size and number, and skin thickness.

The results from storage experiments with many commercially grown samples of Cox's showed the useful effect of gas storage in prolonging the storage life of the apples, in some cases with a marked reduction in wastage by *Gloeosporium*. An examination of these rots revealed that this reduction in wastage was found where *G. album* was causing most of the rots and not where *G. perennans* predominated (p. 140). Other indications from these experiments are that light soils, arable culture and high rates of applied nitrogen tend to be associated with high wastage through rotting, and that the use of captan for the scab spray programme as well as during late summer was valuable in reducing the number of rotting apples.

The possibility of strains of Cox's of different storage quality is being tested with a set of trees on M.1X that was planted out in 1958 at the Station and on two similiar sets on virus-tested M.VII now being planted on commercial holdings.

This whole programme of work is being carried on in close collaboration with Ditton Laboratory, with help on the composition and structure of the cell walls by the Biophysics Department at Leeds University (p. 39).

Summary

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Papers already accepted for publication in the current VOLUME 34 (1959) have been received from both the sponsor Stations, the Glasshouse Crops Research Institute, the National Vegetable Research Institute, the Scottish Horticultural Research Institute, the John Innes Horticultural Institution, Nottingham University, the Citrus Research Station, Nelspruit, South Africa and the West African Cocoa Research Institute, Ghana. Some of the subjects dealt with are the performance of apple rootstocks in the field, the resistance of certain of them to *Phytophthora cactorum* and root development of apple trees under grass sward and clean cultivation. A series of papers on the effects of environment on raspberries has commenced. Other papers describe the performance of selected navel oranges; the effects of shade reduction and manuring on cocoa, of auxins on the development of figs, of temperature on frost resistance of apple flowers; the infection of wounds by *Gloeosporium perennans*; chemical control of strawberry eelworms; the transmission of star crack virus of apples and the effects of virus diseases on the yield of hops; big bud mite of black currants. Vegetable papers deal with the development of tomatoes; the effects of weeds on onions and red beet and of irrigation on summer cauliflowers; and an instrument for measuring the firmness of brussels sprouts is described.

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